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**PROGRAMMATIC LIFE CYCLE ENVIRONMENTAL ASSESSMENT  
FOR SMOKE/OBSCURANTS**

VOLUME 1 OF 5 VOLUMES

**FOG OIL, DIESEL FUELS, AND POLYETHYLENE GLYCOL (PEG 200)**

PREPARED BY

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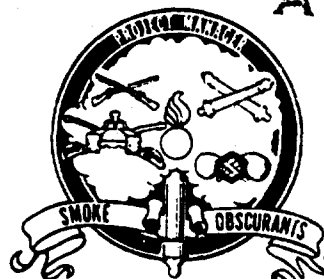
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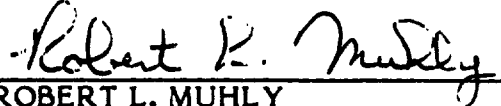
Programmatic Life Cycle Environmental Assessment  
for  
Smoke/Obscurants

Volume No. 1 of 5 Volumes


Fog Oils, Diesel Fuels, and Polyethylene Glycol (PEG 200)

July 1983


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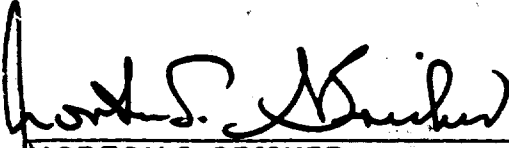
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Petroleum distillate type smoke/obscurants have been used extensively in the past and will continue to be used widely in the future. Their prime function is to obstruct the visual spectrum and conceal the movement of friendly troops in the battlefield. The environmental impacts associated with the use of these compounds for testing and training purposes have been reviewed and compiled in this report. Based on the toxicological data gathered and the regulatory aspects associated with the use of these smoke/obscurants it was concluded that this portion of the smoke program will not significantly affect the quality of the human environment.		

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## PREFACE

This is the first volume of a 5-volume series of documents published to provide a general Environmental Assessment (EA) of the smoke/obscuration program. This volume provides pertinent information on fog oils, diesel fuels, and polyethylene glycol (PEG 200). Volume 2 identifies phosphorous smokes; Volume 3, IR smokes; Volume 4, HC smokes; and Volume 5, dye/colored smokes. Volumes 2-5 will be published in sequence.

This document is not site or item specific, however, it is intended to be used as a basic document in the preparation of related item life cycle environmental documentation, as well as a major supportive reference to environmental documentation prepared for individual site specific operations. Henceforth, as new studies are completed and/or other smoke/obscurants or munitions are proposed, supplemental information will be published.

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## FOG OILS, DIESEL FUELS, AND POLYETHYLENE GLYCOL (PEG 200)

### I. PURPOSE AND NEED

The Army employs smoke/obscurants principally to obscure or screen the movement of troops and vehicles. The ideal smoke screen will hug the ground and remain low to conceal the location and movement of troops. Smokes have critical importance in neutralizing enemy sensors and hiding friendly forces and material. This is accomplished by denying enemy information, reducing effectiveness of enemy target acquisition means, and by creating conditions to deceive and surprise the enemy. Smoke screens can also be used offensively for immobilizing enemy troops by obscuring their vision.

The current smoke generators that are type classified (accepted as standard military equipment) use petroleum distillates.\* Petroleum distillates are not a specific chemical compound but a blend or mixture of hydrocarbons having specified viscosities and other physical parameters. Until future prototype generators which can use other smoke/obscurants in addition to oil are type classified, the use of petroleum distillates will be required for research and development (R&D) purposes and troop training. It is imperative that these distillates are maintained because current infrared (IR) smokes are much less effective in the visible region of the electromagnetic spectrum. Oil smokes can be generated easily from existing munitions and generators, effectively creating a white smoke that screens and obscures the visible spectrum to the maximum.

For these reasons the Army must be prepared to employ smoke and to fight effectively in a smoke environment against an enemy who is trained and equipped for the same operations. Since the recent reestablishment of smoke generating units within the active army, troops must be trained to use smoke generating equipment in realistic scenarios. Such training is essential to effect smoke employment concepts and countermeasure readiness.

### II. DISCUSSION/DESCRIPTION OF ACTION

#### A. History.

The earliest modern method of producing smoke for screening and obscuration was based on the incomplete combustion of the crude fuel oil under the boilers of Navy vessels. Crude oil when incompletely burned (oxygen deficient) evolves a dense black smoke that derives its opacity from particles of colloidal carbon floating in the air. This was done as early as August 1913, in the course of United States Navy maneuvers off Long Island.

During World War II, a method of smoke generation was developed based on the formation and dissemination of minute oil particles by a vaporization-condensation

\*Type classification. Identifies the life cycle status of a materiel system by the assignment of a type classification designation and records the status of a materiel system in relation to its overall life history as a guide to procurement, authorization, logistical support, assets, and readiness reporting.



mechanism. At that time the M1 and M2 smoke generators as well as smoke pots were developed during this time frame using the oil vaporization-condensation process. Appendix A lists the location, type of munition, and amount of fog oil used during World War II.

#### B. Description of Dissemination Modes.

There are various modes of disseminating an oil smoke/obscurant. The primary technique used for dispensing an oil smoke is by mechanical generator systems, which vaporizes the petroleum distillate and disseminates it by means of a fuel driven engine. Other techniques or modes would be the Vehicle Engine Exhaust Smoke System (VEESS) and smoke pots. The VEESS diverts diesel fuel from its fuel tank and disseminates a vaporized smoke cloud with its exhaust. Smoke pots, however, vaporize their fog oil payload by superheating the fog oil to the vaporization point and allowing it to escape through an open valve.

Smoke generators (i.e. M3A3, M52, XM16, and XM52) and the VEESS are considered to be devices of the LASS (Large Area Screening System) category while the smoke pots (i.e. AN-M7 and AN-M7A1) provide small area screens and supplement other smoke sources by filling holes in screens and helping to rapidly establish screens. Detailed data pertaining to standard M3 smoke generators, together with operating and maintenance instruction, are given in TM3-1040-202-12. Information including operating and maintenance instructions on the M52, Smoke Generating Subsystem, Helicopter and on the AN-M7, and AN-M7A1, Floating Smoke Pots is given in TM3-1040-253-13 and TB-CML-100 respectively. Data on all of these smoke disseminators are tabulated in table 1.

The most desirable particle size for a visible-region-effective oil smoke cloud ranges from 0.5 to 1.0 micron. The small drops of oil scatter light rays and produce a smoke which appears to be white. Actually an individual droplet would be transparent under magnification. The droplets are produced as soon as the vaporized oil passes through the nozzle of a thermal generator and is cooled by the surrounding air. The air cools the oil vapor so quickly that only very small drops are formed. The average size of the drop is influenced by the concentration of the condensing vapor and the rate of cooling. Since the oil vapor is ejected from the nozzle at high velocities, large volumes of air are drawn into the vapor stream. The resulting dilution and cooling produces an enormous number of condensation nuclei. The vaporization-condensation process is not dependent on the humidity of the air for the reaction. The petroleum smoke cloud is very stable, and the life of the cloud is determined almost solely by meteorological conditions. In the past, the average field concentrations of oil smoke have been considered harmless to exposed personnel. The smoke is not corrosive to most metals, plastics, or fabrics.

The materials primarily used in smoke generators to produce smoke are low viscosity petroleum distillates, referred to as fog oils and diesel fuels. Fog oils have two standard grades, SGF (standard grade fuel) No. 1 and SGF No. 2. SGF No. 1 has a higher viscosity and is used when the atmospheric temperature is 40°F or above; SGF No. 2 is used when the temperature is between -15° and 40°F. Below -15°F, a mixture of SGF No. 2 and wax-free kerosene has been used in the past. Current Army usage consists primarily of SGF No. 2 for year-round smoke/obscuration use.

Table 1. Dissemination Modes of Oil Smoke/Obscurants

Smoke Disseminator	Type of Smoke/Obscurant Utilized	Range Particle Size Emitted	Storage Capacity	Total Rate of Vaporization
XM16, Truck Mounted, Jet Exhaust, Decontaminating/Smoke System (JEDSS)	Fog Oils* Diesel fuels PEG 200	0.5-1.0 micron	A divided storage tank to contain 600 gal of diesel fuel and 350 gal of fog oil	16 gal/minute
M3A3, Generator Smoke, Mechanical, Pulse Jet	Fog Oils* Diesel fuels PEG 200	0.5-1.0 micron	No storage capacity. Pulls directly from 55-gal drums accompanied.	25-40 gal/hour for fog oil. 35-40 gal/hour diesel fuel.
XM52, Generator, Smoke, Mechanical: Gas Turbine Engine	Fog Oils* Diesel fuels PEG 200	0.5 - 2.0 microns	Same as above	60 gal/hour
M52, Smoke Generating Subsystem, Helicopter (UH-1)	Fog Oils*	0.5 -1.0 microns (SGF No. 2)	50-gallon tank	15 gal/minute
VEESS - used with the following vehicles: M1, M60A1/A3 Tanks, M88A1 MRV, and M551 OPFOR Vehicles	Diesel fuels	0.5-1.0 micron	Dependent upon the fuel tank capacity of the vehicle it is mounted on.	0.4 gal/minute to 1.0 gal/minute (dependent upon the vehicle it is mounted on.
AN-M7 SGF2 and AN-M7A1 SGF2 Floating Smoke Pots	Fog Oils (SGF No. 1 and SGF No. 2)	0.5 - 1.0 microns	Approximately 13 lbs of oil to fill to desired level. (Approx. 1.5 - 2.0 gal)	8-13 minutes to vaporize entire load. (1 - 1.6 lbs/min)

\*Denotes the primary type of smoke/obscurant used for that system.

Recent advances in technology introduced the use of diesel fuel as a smoke/obscurant. The use of diesel fuel will eliminate the necessity for an extra storage tank on combat vehicles for fog oil, since these vehicles are powered by diesel fuel. The VEESS allows a tank or other vehicle to divert some of its fuel to a vaporizer built onto the vehicle. The fuel is then vaporized into a dense smoke cloud and emitted with the vehicle exhaust. Standard diesel fuels used are DF-1 (winter grade), DF-2 (summer grade), DF-A (arctic grade), and DF-Referee grade (minimum quality).

Polyethylene glycol (PEG 200), a nonhydrocarbon, is being evaluated and tested by R&D as a candidate for use as a safe training smoke. PEG 200 can be substituted in most of the smoke producing devices that use fog oil or diesel fuel. It has been used principally to compare its smoke quality and its persistency relative to fog oil and diesel fuel.\* The persistency of PEG 200 was found to be similar to fog oil and greater than diesel fuel.

### C. Types of Petroleum Smokes/Obscurants.

The two principle types of petroleum base smoke/obscurants are fog oils and diesel fuels. Within these two groups are subgroups or grades that will be defined. PEG 200, a polyalcohol rather than a petroleum base hydrocarbon, will also be covered in this report since it is a candidate to replace the petroleum based material. The following sections on physical properties were modified after a fashion and incorporated in this report from volume 4 of 8 of the Liss-Suter Problem Definition Studies on Selected Toxic Chemicals.<sup>1</sup>

#### 1. Fog Oil Properties.

As previously stated fog oils have a relatively low viscosity and consist of two grades, SGF No. 1 and SGF No. 2. The property requirements for both SGF No. 1 and SGF No. 2 are defined by Military Specification MIL-F-12070B.<sup>2</sup>

There is no constant composition for any petroleum product. The composition of diesel fuels, fuel oils, SGF No. 1, SGF No. 2, lubricating oils, and others will vary from product to product and sample to sample. Crude oil source and refining processes are important in producing these variations.

Crude oils are complex mixtures containing thousands of paraffinic, cycloparaffinic and aromatic hydrocarbons, small amounts of sulfur compounds, nitrogen-containing compounds, and other impurities. Crude oils from around the world are classed as paraffinic, naphthemic or asphaltic depending on whether the residues left after distillation are high in paraffins, cycloparaffins, or aromatics; within these classifications there is wide variation from source to source.<sup>1</sup>

The treatment crude oil undergoes at the refinery also affects its composition. Catalytic cracking and related conversion processes favor the formation of olefins, aromatics, and branched paraffins at the expense of other types of hydrocarbons. On the other hand, solvent treating or refining removes aromatics, cycloparaffins, and olefins contained in cracked oils.<sup>1</sup>

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\*The persistency of a smoke cloud is inversely proportional to the vapor pressure.



(a) SGF No. 1. Distillation range, specific gravity, viscosity and pour point are very important in determining hydrocarbon composition. Of these, only distillation range and pour point appear to contribute significantly to limiting the composition of SGF No. 1 (a maximum viscosity is specified, but this high value is not usually attained in products within this boiling range). SGF No. 1 is broadly defined, and therefore, wide variation in composition is possible.<sup>1</sup>

SGF No. 1 corresponds in distillation range to other middle distillate fuels, such as diesel fuel and fuel oils No. 1 and 2. Other properties are also consistent with these fuels. It likely comes from a feedstock originally destined to be one of these fuels, but it differs from diesel fuel as a minimum in that SGF No. 1 is almost pure hydrocarbon since it contains no additives. SGF No. 1 is also higher in viscosity than SGF No. 2 and is therefore considered the summer grade fog oil. However, it has been progressively eliminated from Army smoke program usage and storage quantities have been reduced to nil, because it was found that SGF No. 2 will serve Army needs the year round.

(b) SGF No. 2. The SGF No. 2 sold to the US Army is drawn from a lubricant stock of raw material from various industries. It is a light viscosity lubricant, sometimes called "100 pale oil" because it has a viscosity of 100 Saybolt Universal units (SSU) at 100°F (equivalent in viscosity to a Society of Automotive Engineers (SAE) 20-grade motor oil) and is a pale or straw-colored liquid. In addition to the sources of variation mentioned above, the composition of SGF No. 2 is subject to further variation, because oil companies will draw from whatever stocks are available to fill an order which fits the requirements of the Military Specification.

The SAE motor oils, especially SAE 10 or SAE 20, correspond in viscosity to SGF No. 2 and have a varying hydrocarbon content. One analysis revealed 2.6 mg/100 ml of benzo(a)pyrene in fresh motor oil. However, the presence of additives in commercial lubricating oils makes them dissimilar to SGF No. 2, which is additive free, but since the constituents are primarily the same, analyses of motor oils may be comparable.

SGF No. 2, being a light lubricating oil, is similar in most respects to automotive lubricants and some industrial lubricating oils of similar viscosities. These oils generally have a boiling range of 300-800°C. The hydrocarbons constituting these oils generally contain 20-50 carbon atoms. Based upon viscosity, SGF No. 2 is made up mainly of hydrocarbons in the molecular weight range of 240-420 atomic units.

After the lubricant oil stock is obtained from fractional distillation it is deasphalted to remove constituents which would contribute to carbon residue. At this point it consists of aromatic, cycloparaffinic and mixed aromatic-cycloparaffinic hydrocarbons, which contain paraffinic side chains (often 7-20 carbon atoms in length). The content of aromatic rings in untreated lubricating oil fractions generally varies from 10 to 30%, although 40% has been reported. However, the aromatic hydrocarbons of lubricating stocks produce poor viscosity characteristics, and many are unstable toward oxidation, which transforms them into resinous and asphaltic products. These aromatic hydrocarbons may be extracted by various solvents. The remaining oil is enriched in branched paraffins and cycloparaffins.

These oil distillates normally contain only up to 10% normal and branched alkanes. Typical paraffins present would contain about 25 carbon atoms, with at least one paraffinic side chain, C<sub>4</sub> or longer, in the middle of the molecule. Cycloparaffins with up to four 5-membered or 6-membered rings per molecule predominate.<sup>1</sup>

## 2. Diesel Fuel Properties.

Diesel fuel is a very complex mixture of hydrocarbons containing small quantities of additives. Some diesel fuel is obtained directly from the fractional distillation of crude petroleum oil; the fuels under investigation correspond to that fraction boiling approximately in the range of 160-371°C. Fuels produced in this manner are termed "straight run" distillates by the petroleum industry. The "straight run" distillate usually contains a high proportion of normal alkanes relative to branched chain alkanes and aromatic compounds; it is this high n-alkane content which makes it valuable as a diesel fuel.<sup>3</sup> Additives may also be present in very small quantities to improve combustibility (alkylnitrates), reduce corrosion of storage containers (surfactants), reduce gum formation (mixed surfactant), or act as antioxidants (aromatic amines or phenols).

Diesel fuels come in four grades. The first two are products of the middle distillate oils. They are used in high-speed engines such as tractors, trucks, and buses. Other grades of diesel fuel are more viscous, containing blends of higher-boiling distillates and some residual (nonvolatile) fuels. These are used in low-speed engines operating with sustained loads at constant speeds such as large marine and railroad diesel engines. The acceptance criteria and specifications for these fuels are outlined in Federal Specification VV-F-800C and Military Specification MIL-F-46162B (ME) respectively.

(a) Arctic-grade diesel fuel oil. DF-A is intended for use in high-speed automotive-type diesel engines, gas turbine engines other than aircraft, and pot-type burner space-heaters, in areas where ambient temperatures lower than -32°C generally occur, and where it is impractical to maintain dual storage capabilities. This grade of diesel fuel should not be used for slow-speed stationary engine applications.

(b) Winter-grade diesel fuel oil. DF-1 is intended for use in high-speed automotive diesel engines and gas turbine engines other than aircraft, in areas where ambient temperatures as low as -32°C may occur. This grade of diesel fuel may be used for medium-speed stationary engine applications where fuel heating facilities are not available.

(c) Regular-grade diesel fuel oil. DF-2 is intended for use in all automotive high-speed/medium-speed engine applications and gas turbine engines other than aircraft, for use in moderate temperate climates.

(d) Referee grade diesel fuel represents the minimal or marginal quality level which can be procured under VV-F-800C while meeting all of its requirements. It is designed to be equivalent to the quality of OCONUS distillate production or that production available in times of national emergency. It is used for research, development and proof testing to assure that all diesel fuel-consuming equipment will perform adequately with all diesel fuels procured under VV-F-800C.

## 3. PEG 200 Properties.

Polyethylene glycols, high molecular weight polymers, are dihydroxy derivatives of the paraffins with the general formula  $H(OCH_2CH_2)_n OH$ . The "n" may range from one to a large number yielding a molecular weight from 200 to 10,000. PEG 200, a liquid of mean molecular weight 200, is the lowest member of the series to be generally considered as a polyethylene glycol, and with this polymer, "n" is approximately

equal to 4. The physical state of PEG 200 is that of a water-white odorless liquid. PEG 200 has an extinction coefficient that is relatively close to that of fog oil and diesel fuel which gives it a screening ability equivalent to fog oil and makes it almost twice as effective as diesel fuel in screening length. The heat of vaporization is slightly higher for PEG 200 than for fog oil or diesel fuel.

PEG 200 was selected for consideration as a smoke/obscurant because of its potentially less hazardous nature relative to fog oil and diesel fuel. It was selected on the basis of established medical and toxicological data, in particular, its use as a safe food, drug, and cosmetic additive; and the fact that many of the glycols have been accepted for use in the medical treatment of certain respiratory diseases. (e.g., as a medicinal carrier to the inner reaches of the lungs.)

Polyethylene glycols in general are bland and of low order toxicity. They are extensively used in industry as lubricants, plasticizers, binders, and for other similar applications. In the pharmaceutical industry, they are widely used as components of water-soluble ointment bases, soluble dressings for wounds, carriers for penicillin, sulfa drugs, and peroxides, and in suppositories where they serve as the base and the carrier. In cosmetics they are used in skin conditioning creams, aqueous hair dressing, and as solvents for dyes used in lipsticks.

Significant physical and chemical properties of the three primary military smoke-producing liquids are listed in table 2. Tabulated information giving physical and chemical properties of fuels that correspond to SGF No. 1, DF-A, DF-1, and DF-Referee Grade is included in the CHRIS data sheets found in appendix B along with the previously referenced military requirements specifications.

#### D. Effects of Climatic/Geologic Conditions on Dispersion Clouds.

The effects of weather, particularly wind speed and direction, and terrain conditions are important factors to be considered in smoke screening operations. The movement of smoke depends upon the speed and direction of the wind. Wind direction and velocities are important when estimating the amount of smoke producing equipment and/or fog oil, diesel fuel, and PEG 200 required for smoke operations. Other factors to be considered are temperature, temperature gradient, humidity, precipitation, and cloud cover. Refer to appendix C for further details.

#### E. Dissemination Models.

A computer analysis of downwind airborne concentrations of screening aerosols emitted by the XM16, JEDSS, the device which disseminates the greatest volume of vaporized fog oils as compared to the other generating systems, is provided in appendix D. As with any computer model, predictions are functions of several variable environmental parameters, including wind speed and direction, temperature, atmospheric stability, and terrain. An important assumption of this analysis is that diesel and fog oil screening aerosols -because of their small droplet size (1 micron) and low specific gravity - will not settle beyond a 20-meter arc about the jet engine, but will remain airborne until evaporation (conversation with R. O. Pennsyle, Systems Development Division, April 1982). This important assumption is theoretically sound but requires experimental verification. Presently the Chemical R&D Center, is developing a computer program that will predict possible deposition rates, however, these rates will be so minute that deposition will be negligible. Although the XM16, JEDSS, disperses the greatest volume of oil smoke screening material by vaporization, modeling of the XM52 smoke generator

Table 2. Significant Physical and Chemical Properties of the Three Primary Current US Smoke-Producing Liquids.<sup>4</sup>

LIQUID PHYSICAL PROPERTY	FOG OIL (SGF-2)	DIESEL FUEL (DF-2)	POLYETHYLENE GLYCOL 200 (PEG-200)
Density @ 60°F, gm/cm <sup>3</sup>	0.920	0.850	1.127
Density @ 60°F, deg, API	22.4	35.5	NA
Mean Vapor Pressure @ 25°C, mmHg	1.6 x 10 <sup>-5</sup>	2.5 x 10 <sup>-2</sup>	2.9 x 10 <sup>-6</sup>
Viscosity, (centistokes)			
@32°F	300.0	8.3	230.0
@60°F	80.0	5.0	80.0
@100°F	22.5	2.9	24.0
@210°F	3.5	1.2	4.3
Characterization Factor, K	11.4	11.7	NA
Mean Average Boiling Point, °F	700.0	510.0	590.0
End Point Distilla- tion Temp, °F	870.0	650.0	770.0
Mean Specific Heat of Liquid, from 70°F to Mean B. Pt., BTU/lb °F	0.58	0.55	0.72
Heat of Vaporization @ Mean B. Pt., BTU/lb	92.0	104.0	160.0
Mean Molecular Weight, lb/lb-mole	300.0	205.0	201.0
Heat Required to Vaporize BTU/gal <sup>(*)</sup>	3,565.0	2,515.0	5,235.0

\*From a liquid initially at 70°F to a vapor having a superheat at 20°F. (The comparable value for water is 9340 BTU/gal.)

which has a lower dispersion ability is also included in appendix D. Both models were computed for a one-minute dispersion period. This approach facilitates calculations of downwind exposures following any operation cycle (e.g., simply multiply baseline estimates by the number of minutes per trial). In addition, peak concentrations (in milligrams/cubic meter) are easily obtained, since for one-minute time periods concentration and dosage parameters (milligrams x minutes/cubic meter) are identical.

These models calculate and plot downwind dosages of aerosol smoke clouds. While safety criteria was established using Threshold Limit Values (TLV),\* a determination of hazardous distances using TLV on these models requires conversion from concentration to dosage. The TWA (time weighted average) for healthy adult humans exposed to oil aerosols in an enclosed building is 5 mg/m<sup>3</sup> and the STEL (short term exposure limit) value is 10 mg/m<sup>3</sup>. The TWA value is a concentration based on chronic exposures for 8-hour work days, 5 days a week. Since these values are for concentrations of indoor chronic exposures, they are not that relevant to the smoke/obscurant program, but may be used to approximate health and safety criteria for exposed personnel working in the smoke clouds of the various disseminators.

### III. REGULATORY ASPECTS

#### A. Resource Conservation and Recovery Act.

The Resource Conservation and Recovery Act of 1976 (RCRA), Public Law (PL) 94-580, is the statutory basis for federal regulation of solid and hazardous waste. US Environmental Protection Agency (EPA) has promulgated regulations implementing RCRA (40 CFR 260-264; 265-267) that identify and provide management requirements for the disposal of solid and hazardous wastes and promote resource conservation and recovery. The regulations list approximately 400 hazardous chemical wastes and 85 process wastes. If not specifically listed, a waste may be hazardous if it exhibits one of the following characteristics: (as defined by the regulation) reactivity; corrosivity; ignitability, or toxicity. State and local regulations may impose more stringent requirements not present in the federal regulations.

These waste fog oils and diesel oils do not display any of the RCRA hazardous characteristics and are not listed by RCRA. These oils are not contaminated with pollutants such as PCBs but are strictly waste to be recycled through Defense Property Disposal Office.

#### B. Toxic Substance Control Act.

The Toxic Substance Control Act (TSCA) of 1976 (PL94-469) mainly addresses the commercial manufacture, use, and distribution of chemical substances. The act

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\*Threshold limit values (TLV's) are published by the American Conference of Governmental Industrial Hygienists, and refer to airborne concentrations of substances believed safe to "nearly all workers" following repeated daily exposure. The two categories of TLV referenced above are specified as follows:

(a) TLV-TWA, "the Time Weighted Average concentration for a normal 8-hour workday or 40-hour work week.

(b) TLV-STEL (Short Term Exposure Limit), "a maximal allowable concentration, or ceiling, not to be exceeded at any time during the 15-minute excursion period.

authorizes EPA to obtain premanufacture toxicity testing and the generation of sufficient data on a chemical to predict any environmental hazards associated with its production or use. A manufacturer must notify EPA 90 days prior to commercial production of a new chemical substance.

The use of smoke munitions by the Army for testing and training should not be effected by TSCA because present smoke materials were developed before TSCA became effective and were inventoried on the initial TSCA Inventory list (45 FR 505444, 29 July 80).

### C. Clean Air Act.

The Clean Air Act (CAA), PL88-206 as amended, establishes National Ambient Air Quality Standards (NAAQS) for the control of criteria air pollutants to prevent adverse effects to national air resources and to protect human health and the environment. Among criteria pollutant standards, those most likely to affect the smoke/obscurants program are presented in table 3. Until recently the emission of hydrocarbons was regulated by the NAAQS, however, on 30 December 1982 the hydrocarbon national ambient air quality standard was rescinded by the EPA. According to the EPA, because no consistent quantitative relationship between ambient air ozone concentrations and hydrocarbon air quality levels exists, the original basis for the hydrocarbons standard could not be justified.

Table 3  
Federal Ambient Air Quality Standards for Certain Criteria Pollutants

<u>Chemical</u>	<u>National Standards</u>
Particulate Matter	(A) 75 $\mu\text{g}/\text{m}^3$ annual geometric mean. (B) 260 $\mu\text{g}/\text{m}^3$ - maximum 24-hour concentration not to exceed more than once per year.
Ozone	0.12 parts per million (235 $\mu\text{g}/\text{m}^3$ ). The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 parts per million (235 $\mu\text{g}/\text{m}^3$ ) is equal to or less than 1

Under the CAA, the country is divided into 247 air quality control regions (AQCRs) to provide basic geographical units for air pollution control. States are required to prepare State Implementation Plans (SIPs) to implement and enforce criteria pollutant standards in those regions. State standards are often more stringent than federal standards, and vary from one AQCR to another. AQCRs that have attained the NAAQS for a criteria pollutant are considered to be in "attainment" for that pollutant. AQCRs in violation of NAAQS for a criteria pollutant are considered "non-attainment" for that pollutant. Most standards specify two types of limitations - long-term standards which cannot be exceeded on an annual average and short-term exposures which cannot be exceeded for brief periods (e.g., 3 hours and/or 24 hours). By definition, when smokes/obscurants are used in training and testing, the standards for certain criteria

pollutants may be temporarily exceeded in the area of the test or training site. The Army environmental coordinator at the test or training site should be consulted for coordinating the smoke exercises with the local regulatory agencies for permits or variances as required.

D. Federal Regulations Governing Oil and Hazardous Substance Release into the Environment.

Control of discharges of oil and hazardous substances into the environment are detailed in Federal Water Pollution Control Act (FWPCA) (PL95-576) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (PL96-510). Section 311 of FWPCA describes requirements for handling of spills of oil and hazardous substances. A spill is defined as the release or discharge of regulated pollutants not covered by permit by pumping, pouring, emitting, emptying, leaking or dumping. Harmful quantities of a hazardous substance are defined as any discharge that violates state water quality standards adopted by the state and approved by EPA pursuant to Section 303 of FWPCA. An oil spill is defined as that which causes a film or sheen upon the surface of water or adjoining shorelines.

EPA has promulgated regulations under the FWPCA which identify and establish reporting requirements for approximately 270 hazardous substances. Reporting requirements are based on harmful quantities as defined by the regulation.

Each Army installation with the capability for a release of a reportable quantity of oil or hazardous substance to the environment is required pursuant to AR 200-1 to prepare, maintain, and implement a Spill Prevention and Countermeasure Control (SPCC) Plan and an Installation Spill Contingency Plan (ISCP). These plans establish procedures to prevent spills and to ensure prompt reporting, containment, and cleanup of spills. Procedures for spill events are outlined in Army Regulation 200-1, 15 July 1982.

CERCLA also establishes reporting requirements for the release of hazardous substances into the environment including land, air, and water when the release occurs in amounts equal to or greater than the reportable quantity. Hazardous substance as defined by CERCLA includes any substance designated or listed in: FWPCA, Sections 307 and 311; RCRA, Section 3001; CAA, Section 112; and TSCA, Section 7. Reportable quantity for any hazardous substance is one pound unless otherwise specified in Section 311 of the FWPCA.

E. Hazardous Materials Transportation Regulations.

1. Department of Transportation (DOT) Regulations.

Under federal act this agency formulates the regulations for safe transportation of hazardous materials, poisonous substances, explosives, and other dangerous articles. These regulations are binding upon all carriers engaged in the transport of the above mentioned hazardous material, and are in accordance with the best known practices for assuring safety in transit. These regulations also include requirements for packing, marking, handling, and loading of the hazardous materials to be transported or shipped. Modes of transportation covered by the regulation are as follows:

(a) Surface and Air Carriers. Regulations of the DOT governing the safe transportation of hazardous and explosive articles by surface and air modes are in accordance with Title 49, Code of Federal Regulations, parts 171-179.

(b) Water Carriers. All commercial water carriers transporting hazardous materials are governed by the DOT regulations as specified in Title 46, Code of Federal Regulations, part 147.

## 2. Military Regulations.

Explosives and other dangerous articles shipped or transported by the military services are subject to the applicable regulations of the military service involved. Modes of transportation covered by the regulations are as follows:

(a) Surface Carriers. AR 55-355 regulates the movement of military cargo within the United State by commercial vehicle.

(b) Air Shipments. TM 38-250 regulates the safe transport of hazardous articles.

(c) Water Shipments. AR 55-228 regulates shipment and transport of dangerous and hazardous articles by water in conjunction with the US Coast Guard regulations.

## 3. Other Transportation Regulations.

In addition to the federal laws governing the transportation of flammable and hazardous materials, each state and nearly all municipalities have laws or ordinances regulating the transportation of hazardous articles within their jurisdiction. Fog oil and diesel fuel are classified as combustible liquids and should be handled as fuel oils. The transportation or shipment of fog oil and diesel fuel is regulated by the federal regulation expressed in table 4.

Table 4. DOT Hazardous Materials (CFR 49, 172.101)

<u>Name</u>	<u>Hazard Class</u>	<u>Labels Ident No.</u>	<u>Packing Section Required</u>	<u>Maximum Net of CFR 49</u>	<u>Quantity</u>
Fuel Oil (diesel oil and fog oil)	Combustible liquid	UN1201	None	None	No limit

## F. Other Acts.

Regulations on endangered species or historic preservation are primarily site-specific. Installation environmental quality coordinators should be contacted to determine if these regulations are applicable.



#### IV. TOXICITY DATA/STUDIES OF PETROLEUM DISTILLATES AND PEG 200

##### A. Human (Mammalian).

Long-term exposure of humans to petroleum distillate smoke screens had not been fully documented in the past. According to the data gathered in the Liss-Suter reports, short-term medical records from World War II reportedly revealed no indications that smoke generator unit personnel, or military operating in constant smoke screens for long periods experienced any illness, carcinogenic, or mutagenic effects related to exposure to fog oil smoke screens.<sup>1</sup> Additionally, there was no indication that precautions had been taken to avoid exposure at that time.

The toxicological data of vaporized oil clouds and PEG 200 are compiled in appendix E. Since research data of fog oil and diesel fuel was not extensive in the past, toxicological data of similar oils such as mineral oil is also included. The majority of toxicity data pertaining to petroleum distillates compiled in the past addressed liquids or combustion by-products rather than vaporized clouds. Most Army oil smoke systems depend upon vaporization-condensation rather than combustion, however, the VEESSE diverts diesel fuel from its fuel tank and disseminates a vaporized smoke cloud with its exhaust. Studies conducted by Callahan et al., evidenced that the toxic components of the combinant smoke/exhaust cloud appear to be in the diesel fuel combustion gases and not as much in the vapor.<sup>5,6</sup>

As stated in MIL-F-12070B, contained in appendix B, fog oils shall not contain additives, however, diesel fuels may contain additives and a significant amount of the toxicological properties associated with diesel fuels may be attributed to these additives. These additives are regulated in accordance with Federal Specification, VV-F-800C and Military Specification, MIL-F-46162B(ME), also contained in appendix B, and may be required for various reasons including utilization as antioxidants, cetane improvers, corrosion inhibitors, and fuel system icing inhibitors. A small amount of impurities may also be found both in fog oils and diesel fuels but are regulated for acceptance criteria in accordance with the above regulations.

Oil in the lungs may cause edema, pneumonia, and possibly other diseases. Chronic industrial exposures of oils and oil mists have been implicated in causing dermatosis (SGF No. 1) and dermatosis plus tumors of skin, respiratory tracts, and larynx (SGF No. 2), however, whether this is due to an allergic reaction, carelessness, or uncleanness is uncertain. In industry, the recommended maximum allowable TWA concentration of oil mist in workroom air is 5 mg/m<sup>3</sup>. Above this level, the smoke is visible and annoying, however, lubricating oil concentrations up to 402 mg/m<sup>3</sup> have been reported in some shop environments. Unprotected individuals exposed to concentrations of this level for a short period of time demonstrated no reaction. Experimental animals exposed to chronic inhalation of fog oil mists and diesel fuel mists showed some toxic effects. Some of the toxic effects after exposure to these petroleum distillates include pneumonia, nasal hemorrhaging, convulsions, skin and pulmonary tumors, hair loss, and death as evidenced in appendix E.

Starek et al., conducted acute oral toxicity studies with diesel oil on rats. They determined the oral LD<sub>50</sub> to be 16.0 ml/kg for rats.<sup>7</sup> Nau, Neal and Thornton evaluated the inhalation toxicity of C<sub>11</sub>-C<sub>12</sub> aromatic distillates on various mammals and determined an acute LC<sub>50</sub> of 4600 mg/m<sup>3</sup> for rats exposed for seven hours to the aromatic distillate. They also exposed rhesus monkeys to C<sub>11</sub>-C<sub>12</sub> aromatic distillates for 7 hr/day, 5 days/week, for 13 weeks and observed sublethal effects on the monkeys such as eye and skin irritation at levels of 300 mg/m<sup>3</sup>.

SGF No. 1 has been shown to be moderately toxic to rhesus monkeys. Lushbaugh et al., conducted inhalation toxicity studies on rhesus monkeys.<sup>9</sup> The monkeys were exposed to 63 mg/m<sup>3</sup> of SGF No. 1 aerosol for 30 minutes and then 30 minutes of room air for 343 days. Five of the seven monkeys exposed died within 100 days.

Wagner, Wright and Stokinger<sup>10</sup> studied the inhalation toxicity of mineral oil on several mammals and found that hamsters and rabbits exposed to 100 mg/m<sup>3</sup> of mineral oil for 6 hours a day, 5 days a week, for 26 months exhibited no major lung tissue response.

PEG 200 exhibited the lowest toxicity of the liquid smoke materials under investigation. Sprague-Dawley rats received oral doses of 5.0 ml/kg of PEG 200 daily for 13 weeks.<sup>11</sup> No adverse effects were reported. Crook, Hott and Weimer<sup>12</sup> conducted PEG 200 inhalation studies on rats and mice for six hours and observed no toxic effects at levels of 2516 mg/m<sup>3</sup>. Nau et al., conducted inhalation studies of C<sub>9</sub>-C<sub>10</sub> aromatic distillate on rats and found an acute LC<sub>50</sub> of 14,400 mg/m<sup>3</sup> after 7 hours.

#### B. Flora.

Toxicity studies of petroleum distillate smoke clouds have not been completed on flora. Personnel of the US Army Medical Bioengineering Research and Development Laboratory (USAMBRDL), Fort Detrick are tasked to establish the environmental fate of fog oil and diesel fuel. There is some information on the effect of oil base sprays on vegetation. Petroleum oil sprays on fruit and citrus orchards are insecticidal to some species, and may be moderately phytotoxic. Leaf spotting, premature fall of leaves, bark injuries, root injuries, stunting, reduced fruit yield, premature fruit drop, and oil penetration into fruit have been reported.<sup>13</sup> Oil application to leaves of turnips, onions, and other vegetables results in oil contamination of their edible roots. Oil sprays also caused leaf scorching and spotting in foliage trees, and inhibited photosynthesis in banana tree leaves when sprayed at a concentration of 84 µg/cm<sup>2</sup> on leaf surfaces.

Some studies have been done on the toxicity of oils to aquatic plant life, however, this information was based on data gathered from oil spills or mock spills. Data on the toxicity of fuel oils to algae, phytoplankton and bacteria are presented in appendix F. Gordon and Prouse found the 19.8 µg/l of No. 2 fuel oil in water inhibited the photosynthesis of certain marine phytoplankton communities. Other studies indicated effects such as no growth or producing a lag phase in growth of cultures.

#### C. Wildlife.

The literature available on the toxic effects of oils on wildlife have been generated from oil spills. The data on the effects of oils on waterfowl are presented in appendix G. Hartung and Hunt observed sublethal effects on ducks with intragastric diesel fuel doses of 3-12 ml/kg. Although there is some information on the effect of oil base sprays/mists used as a vehicle for herbicides and insecticides, there is no data available specifically on the toxicity of oil smokes to wildlife. As a pesticide, oil sprays are effective primarily because they starve the pest or unwanted organism from acquiring the necessary oxygen required for respiration. This is achieved mainly because the droplet size of these pesticides is several times larger than the standard Army petroleum base smoke/obscurants and tends to settle and adhere to these organisms.

#### D. Aquatic Toxicity.

Oil spills on aquatic environments form a film on the surface of bodies of water. These films are subjected to evaporation, biotransformation, dissolution in water and bioconcentration in aquatic organisms. Some of the petroleum hydrocarbons, mostly the aromatic naphthalenes, dissolve in water. Tainted fish and shellfish result when oil is concentrated in their flesh. Wind, waves, and bottom sediment movement spread oils in the marine environment, destroying bottom plants and animals, reducing the stability of the seabottom and causing erosion and further spread of oil. Bacterial transformation and photooxidation of oils contaminating aquatic environments lead to a more rapid depletion of the aliphatic hydrocarbons than the polycyclic aromatic compounds, which can form tar-like deposits in bottom sediments. In these environments, the oil hydrocarbons are persistent poisons, resembling DDT, PCB, and other synthetic materials in their longevity. The hydrocarbons enter the marine food chain and are concentrated in the fatty parts of the organisms. They can be passed from prey to predator, where they may become a hazard to marine life as well as humans.<sup>13</sup>

The effects of an aerosolized oil smoke cloud on aquatic ecosystems have not been undertaken, however, as the model illustrates deposition should be negligible. The films created by oil spills are drastic. Aquatic toxicity data of such fuel oils and lubricating oil spills are presented in appendix H (the reference to individuals and studies performed are taken from the reference column of this appendix). This evidences the worst possible situation that may arise from the use of petroleum base products and not that of the dissemination of a smoke cloud.

Anderson et al., conducted toxicity tests on fish with No. 2 fuel oil and found a 96-hr TLM of 3.9 mg/l to the silverside (Labidesthes sicculus). Rossi et al., exposed various marine annelids to No. 2 fuel oil and found 96-hr TLM values as low as 2.3 mg/l. Mollusks were found to be sensitive to oil in water, Byrne and Calder exposed Quahaug clam eggs to No. 2 fuel oil dissolved in water and determined a 48-hr LC<sub>50</sub> of 0.43 mg/l. Jacobsen and Boylon found that 4 µg/l of kerosene which is similar to diesel fuel, dissolved in water interfered with the food - finding behavior of the snail (Nassarius obsoletus). Marine crustaceans were moderately sensitive to No. 2 fuel oil dissolved in water. Anderson et al., determined a 48 hr TLM of 0.9 mg/l to the mysid shrimp. Vanderhorst et al., estimated a 96 hr LC<sub>50</sub> to coon stripe shrimp to the 0.8 mg/l. Barnett and Kontogiannis exposed to copepod (Tigropus californicus) to diesel fuel in water and found a 100% 96 hr mortality at 0.50 ml/l.

#### V. ENVIRONMENTAL IMPACTS OF FOG OIL/DIESEL FUEL/PEG 200 AS SMOKE/OBSCURANTS

##### A. Research and Development (R&D) Phase.

Army R&D is subdivided into two phases: Demonstration/Validation and Full Scale Development. During the demonstration/validation phase, smoke generation tests are conducted at installations throughout the United States and abroad that are selected especially for their climate and test site ability (e.g., suitable location, personnel, remoteness, etc.). Site specific environmental assessments are maintained at these installations that describe environmental setting, include local flora and fauna, and any other features and uses of the installation, such as testing facilities. Decisions regarding full scale development depend in large part upon results of Demonstration/Validation testing.

R&D of fog oils and diesel fuels is not ongoing and is not proposed for the future because the quality of their obscuration ability has been known for some time. Historically, oil has been used for years as a smoke/obscurant, however, improvements on the process of dissemination by vaporization have been made. Fog oil and diesel fuel are standard Army items that require no further R&D work. Although PEG 200 has been used for smoke screening and as a chemical agent simulant in training because of its relatively nontoxic rating, it is not a standard Army smoke because of its expense and lack of approval for use in field operations.

Fog oil and diesel fuel smoke/obscurants are used for the evaluation of smoke disseminators undergoing R&D testing. Although R&D of fog oils and diesel fuels is not ongoing, discussions of the impacts associated from the use of these materials in the development of hardware are generically addressed in this programmatic environmental assessment. Specific impacts resulting from the development of a particular smoke munition will be addressed in more detail in the Life Cycle Environmental Assessment for that item. Presently, the Army is testing the effectiveness of the XM52 Smoke Generator and the XM16 Jet Exhaust Decon/Smoke System which has a secondary smoke capability. The VESS and M3A3 are standard Army smoke disseminators, however, they are undergoing reevaluation. The VESS must be evaluated on every vehicle for which it is proposed. The M3A3, smoke generator is presently undergoing a product improvement program (PIP). These two systems must then be evaluated for their ability to disseminate diesel fuel and fog oil respectively.

#### 1. Alternatives Considered:

(a) Indoor Testing or Reduction of Field Testing Requirements. Indoor laboratory and chamber experiments are used to design and test small scale dissemination prototypes, however, full scale models require outdoor or field testing. Many of the measurements and evaluations to be gleaned from results of field tests will involve behavior of smoke screens under different meteorological regimes, and reliability of the equipment when operated for long periods of time. While field testing requirements could be reduced by conducting smoke tests indoors, this approach could require costly and time consuming modifications to large buildings..

Attempts to limit the number of diesel or fog oil screening tests for development and training would run the risk of fielding a system without adequate assessment of performance under realistic conditions. In view of the importance of the large scale smoke/obscurant program to Army needs, the risks associated with the fielding of an improperly tested item are too great to justify.

(b) Modify Existing Systems. Currently the US Army uses the M3A3 smoke generator and the M7 and M7A1 floating smoke pots, all of which dispense aerosolized fog oil as the primary smoke material. However, these systems have several limitations. The M3A3 must be dismounted from a quarter-ton trailer before use, i.e., it cannot function from a moving vehicle unless some local creative engineering techniques are applied. A trailer-mounted M3A3 cannot keep pace with armored or mechanized forces, and the generator is quite vulnerable to artillery fire, small arms, and automatic weapons. The M7 series floating smoke pots carry small payloads that are expended in 8-13 minutes. They produce an oil smoke by using a mechanical fuze to ignite a fuel block which in turn heats the oil to vaporization. In the past fuze problems have prevented ignition of the fuel block, thereby disallowing the oil to vaporize. Modifications necessary to improve these systems would still require PIP testing resulting in the same effect as R&D testing of a new system. R&D of new methods of screening with oil

smokes will augment present capabilities and surpass the limitations imposed by the current systems.

(c) Test With PEG 200 Only. PEG 200 can be substituted in most of the systems that disseminate fog oil or diesel fuel, although it is not a feasible alternative for the VEESS which utilizes diesel fuel from its own fuel tank.

(d) No Action (Do Not Develop New Systems). The need for new smoke systems with increased ability of obscuration and the resultant use of petroleum distillates to test these systems is considered to be urgent. Thus, the "no action" alternative would be inconsistent with current requirements for national security.

## 2. Environmental Impacts of Activities and Alternatives.

(a) R&D Test Impacts. Much of the evidence of impacts from petroleum distillates to natural ecosystems is associated with oil spills, or with agricultural damage following application of oil sprays (i.e. as oil droplets 100 microns or more in diameter). In either instance, soils, plants, and other lifeforms were covered or coated with oily films. Aerosols of 1 micron sized microdroplets do not coat surfaces like conventional oil sprays. Instead they are expected to remain airborne and eventually evaporate or disperse as previously mentioned under the modeling section of this report. Therefore, estimated exposure rates, particularly to plant and soil communities, must be interpreted from the available data with caution.

Under conditions described for the models, in appendix D, airborne concentrations from the various smoke tests of different smoke generators would tend to remain within the TLV stated for short distances downwind, dependent upon the duration of smoke emission. These concentrations can be expected to transiently affect other natural populations in these areas.

Risks, while largely unavoidable for some wildlife, may be mitigated by the observation that certain species of wildlife (i.e., deer, birds, etc.) tend to leave during field testing and return afterwards. Oral ingestion of quantities of petroleum distillates as illustrated in appendices E and G, relates to ingestion of vegetation that would be oil soaked or saturated. Messerli<sup>14</sup> documented that a cow after accidental ingestion of approximately 7 liters of diesel fuel demonstrated ill symptoms for 8 days before recovery. A ewe after ingestion of diesel fuel soaked grass also demonstrated ill symptoms as documented by Ranger.<sup>15</sup> Both cases resulted from spills rather than saturation from smokes. Domestic animals or humans within exposed sections of the test range by timely posting and notification procedures can avoid these areas thereby mitigating the situation. However, resident rabbit and rodent populations are not that transient and will be subjected to these sublethal exposures, but as evidenced in appendix E in conjunction with the model information in appendix D exposures from R&D testing are short term and concentrations would not be high enough to cause permanent population damage.

Aquatic ecosystems should be relatively unaffected by the oil once it is dispersed as an aerosol smoke as evidenced by the modeling of oil smoke clouds (conversation with R. O. Pennsyle, Systems Development Division, April 1982). Site specific ISCP and SPCC plans govern the possible spill of oils on post. These control plans will serve in mitigating any possible adverse conditions that may occur from oil spillage and impact on aquatic or terrestrial ecosystems.

Environmental impacts from noise as a result of smoke generation are from the generators. The XM16, a worst case situation because of its jet-turbine engine, is capable of noise levels in excess of 140 dB-A. Test personnel are required in all cases to wear hearing protection devices within an 85 dB-A isopleth, as required by AR 200-1. A grid showing the 85 dB-A isopleth distance for the XM16 in various positions is included in appendix I. Other generating systems have much lower dB-A levels and would require a lesser distance for hearing protection.

The generation of smokes/obscurants impacts directly on local air quality. The quality of this air is protected by federal, state, and local air pollution control regulations as discussed in section III. Standards are extremely variable from state to state and are usually written for maximum three-hour concentrations not to be exceeded more than once a year. Notification of regulatory agencies may be required for permits or variances prior to smoke generation tests/training.

The primary pollutants discharged by the generation of petroleum-based smokes (noncombusted) are particulates and hydrocarbons. Particulates generally are not as harmful as other pollutants but particulate pollution is the most visible and, therefore, tends to cause most public concern. Respirable size particulates can aggravate the respiratory systems of humans/wildlife and may be particularly aggravating to susceptible recipients such as the young, the old, and those with respiratory problems.

Major sources of net particulate emissions include the construction materials industry, electric utilities (principally coal-fired utilities), fuel combustion by industrial boilers, and steel production.<sup>16</sup> These major sources accounted for 81 percent of the total particulate emissions for the year 1975. Of the 81 percent, construction materials industry accounted for 41 percent and electric utilities for 24 percent. Other undefined sources accounted for 19 percent of the total net emissions, each of which emitted less than 6 percent of the total. Emissions based upon smoke testing account for an insignificant amount of this total.

Urban air may contain from 50-200 different hydrocarbons. Only about 15 percent of total atmospheric hydrocarbon is produced through human activities. Much of the natural hydrocarbon is methane arising from bacterial decomposition in swamps and other water bodies. Such natural hydrocarbon is released over wide areas and is not usually a significant contributor to urban oxidant problems. Many hydrocarbons are harmful only in high concentration. Of the net hydrocarbon emissions in 1975, more than half were due to transportation, with automobile travel accounting for 60 percent and trucking, 40 percent. These releases, through interactions with nitrogen oxide emissions, probably contributed to major air quality problems, as more than three-fourths of the urban counties in the United States failed to attain the primary National Ambient Air Quality Standard for photochemical oxidants.<sup>16</sup>

Photochemical oxidants are a class of compounds that are the products of reactions involving nitrogen oxides, hydrocarbons, oxygen, and sunlight. These strongly oxidizing agents, the major constituents of photochemical smog, are chemically and biologically active compounds that are potentially harmful to health and environment. Since the major toxic product of these photochemical reactions is ozone, air quality standards regarding photochemical oxidants pertain to ozone. Ozone is a harmful pollutant and is host to a complex series of continuing reactions that occur at different rates of speed that continue as long as ozone or nitrogen dioxide and strong sunlight are present. Measures taken to mitigate the production of these photochemical oxidants from the addition of uncombusted hydrocarbons to the atmosphere should

include the imposition of restrictions to testing/training based on weather conditions, time of year, location, etc.

It is possible that for short periods of time combined aerosol and exhaust emissions from smoke generation tests may not comply with emission standards as defined in Title 40, Code of Federal Regulations, parts 85 and 87. However, as evidenced these short burst emissions are not as severe as the continuous emissions of pollutants by industry. Sites for smoke generation trials are chosen so that they are located as far as possible from ecologically-sensitive areas, installation boundaries, and populated areas.

(b) Impacts of Alternatives.

(1) Indoor Testing or Reduction of Field Testing. Indoor smoke testing would eliminate certain environmental risks associated with field smoke testing but at the expense of creating other environmental impacts while preparing structures to house such tests. Impacts of outdoor smoke testing are not great enough to justify expenditures for indoor testing of all the various smoke generating systems. Reduction of field testing would lessen any possibility of environmental impacts, however, only by increasing the possibility of fielding a system that has been improperly tested.

(2) "Modify" Existing Systems. Modification of the existing smoke generation systems would still require PIP testing. Field testing under the PIP status would have essentially the same impact on the environment as R&D testing of new smoke generation systems, however, with only a temporary improvement to an old system rather than an entirely new designed system.

(3) Test with PEG 200. PEG 200 has been evaluated toxicologically and found to be environmentally safer than diesel and fog oils as a screening material. However, it is not accessible, is more expensive than fog oil and diesel fuel, and is not an approved standard Army item. Attempts to substitute PEG 200 for developmental testing would also run the risk of fielding a system without adequate assessment of performance using petroleum distillates for which it is designed.

(4) No Action. This alternative would eliminate all direct environmental impacts associated with R&D testing, but is unacceptable in view of current requirements for national security.

3. Recommended Mitigations.

(a) The Army, when tasked with R&D testing, uses only the minimum amount of material necessary for evaluation of any system to lessen any possible environmental impacts. Additionally, any spills that may occur should be kept to a minimum since the oils are transported, stored, and used in 55-gallon drums.

(b) During early phases of R&D, tests are primarily conducted in fully sealed environmental chambers to minimize impact to the environment.

(c) Outdoor testing is limited to specified wind direction and speed ranges, specified lapse conditions, quantity of material for individual tests, and for total quantity tested at a particular site to minimize negative environmental impacts.

(d) All testing is maintained within the guidelines prescribed for each site specific installation land use plans and requirements.

## B. Manufacturing/Production Phase.

All fog oil, diesel fuel, and PEG 200 are produced and purchased by bid from commercial suppliers who are currently marketing these materials. Hence, no unique or additional pollutants would be generated. These bids are funneled through the Defense Fuel Supply Agency and purchases are made upon a supply necessity. Acceptance criteria are based on the military standards previously noted and handled by the receiving agency for inspection. All of the smoke generators and munitions listed in table 1 are manufactured and supplied to the Army by commercial industry. Once the system is in full scale development and the design and producibility are acceptable, the Army will contract outside industry to go into full scale production of the item.

### 1. Alternatives Considered.

There are no alternatives to be considered under this phase, since the Army does not have access to oils other than from commercial sources nor do they have the facilities for mass production of smoke generators. Assembly of metal components and heat block purchased from industry for the production of smoke pots was handled at the Edgewood Area of Aberdeen Proving Ground, however, that operation was discontinued approximately 15 years ago. The "no action" alternative would be inconsistent with current requirements for national security.

### 2. Environmental Impacts of Activities.

When industry is contracted by the Army to supply services or materials they are required by federal law to stay within the guidelines presented in Title 40, Code of Federal Regulations, Part 15 on the administration of the Clean Air Act and the Federal Water Pollution Control Act. Furthermore, they are required to comply with state and local regulations governing the area in which production occurs. Impacts associated with production lots should be the same as those discussed in the R&D section.

## C. Training and Deployment Phase.

Smoke screens are used in training to cover a designated area or target for a specified time in support of a tactical plan. No two missions are likely to be the same, but the most immediate factors of concern are the size of the area to be covered, the nature of the terrain and vegetation, and the meteorological conditions. The size of the area to be covered obviously determines the amount of smoke needed. The smoke planner consults tables which relate these factors to the distance between generators which in turn determines the number of generators needed. The position and shape of the generator line would be determined by the terrain. It would be positioned several hundred meters upwind of the target area to be sure the individual smoke generator streamers diffuse and mix together so that the target is covered by a screen of uniform density. Depending on the mission, a dense cloud allowing almost no visibility or a light haze allowing visibility up to 100 meters may be required. As the mission continues the smoke cloud is watched closely to determine the adjustments needed. If the screen is too dense generators are turned off or moved farther apart. If the screen is too thin the generators are moved closer together. Generator location is changed according to wind direction.

The smoke training exercises present the students with an area to be covered and the duration of coverage. The students then plan and execute the operation under the supervision of instructors. Up to 48 generators may be used per exercise depending



on the type of generator used and the area to be covered. A training exercise usually requires making smoke for approximately two hours. Smoke material used is primarily SGF No. 2; diesel fuel is used when training with the VEESS. PEG 200, is also used occasionally, as a simulant, for safe troop training purposes. As the exercise progresses, the instructor would carefully observe the cloud and the meteorological conditions with a view toward terminating the exercise should smoke be likely to effect areas outside the designated exercise area.

## 1. Alternatives Considered.

(a) Train Indoors or Modify Training Requirements. Initial classroom training to familiarize troops with smoke environments is standard, however, full scale training is conducted outdoors. Modifications to large buildings would reduce the amount of smoke training conducted outdoors, but would require a potentially costly and time consuming effort. Attempts to limit the number of diesel or fog oil training exercises would run the risk of fielding troops without adequate assessment of performance under realistic conditions. In view of the importance of the large scale smoke/obscurant program to Army needs, risks associated with fielding improperly trained troops would be too great to justify.

(b) Train With PEG 200 Only. PEG 200 can be substituted in most systems that disseminate fog oil or diesel fuel, although it is not a feasible alternative for the VEESS which utilizes diesel fuel from its own fuel tank. Training with PEG 200 could be used for essentially all the oil disseminating systems.

(c) No Action (Do Not Train). The need for qualified troops knowledgeable of smoke/obscurants is considered to be urgent. Thus, the "no action" alternative would be inconsistent with current requirements for national security.

## 2. Environmental Impacts of Activities and Alternatives.

(a) Present Training Impacts. Since training and testing occur in much the same type of environment, impacts to the environment resulting from training with smoke generating devices will be similar to those impacts resulting from testing the devices and are addressed in Section VA.

### (b) Impacts of Alternatives.

(1) No Action Alternative. This alternative would eliminate all direct environmental impacts associated with training, but is unacceptable in view of current requirements for national security.

(2) Train Indoors or Modify Training Requirements. Indoor smoke training would eliminate certain environmental risks associated with field smoke training, but at the expense of creating other environmental impacts while constructing structures to house such training. Impacts of outdoor smoke training are not nearly great enough to justify expenditures for indoor training of all the various smoke generating systems and the subsequent training program delays pending construction. Additionally, reduction in training requirements would be unacceptable in view of current requirements for national security.

(3) Train with PEG 200. PEG 200 has been evaluated toxicologically and found to be environmentally safer than diesel fuel and fog oils as a

screening material. Although it is approved by the Surgeon General for troop training exercises, it is more expensive and not as accessible as fog oil and diesel fuel and is not an approved standard Army item. Substituting PEG 200 for troop training would run the risk of fielding troops without adequate training with petroleum distillates for combat situations.

### 3. Recommended Mitigation.

(a) Select appropriate weather conditions which for the most part confine the cloud to the military reservation. (i.e., Do not deploy during air pollution episode alerts).

(b) Range Control should receive notification of smoke use in order to assure dispersion of use over time and space. When a pattern of excessive usage appears, coordination with the unit commander should be sufficient to resolve it. Areas and conditions for potential use should be precisely stated in range regulations, and the areas should be as large as possible to reduce concentrations. Areas of heavy use, particularly those areas near aquatic systems, should be monitored periodically for ecological changes. This implies that there be some precise description of such areas before smoke use as a "baseline" comparison. Regulations and training should also address the matters of proper munition or generator use to prevent contamination from improper usage and fire damage from burning munitions.<sup>18</sup>

(c) Before major use of smoke munitions, Range Control should coordinate with or notify appropriate Air Pollution Control Authority, Post Fire Department, Post Forester, airfield control tower, and other appropriate specified agencies. "Major" use which would trigger these actions is defined as use of mechanical smoke generator (M3A3), helicopter-mounted smoke generating subsystem (M52), or more than three smoke pots. Road guards should be provided as necessary under any use by the unit carrying out the training, in order to provide warning at cloud limits along military-use roads. A ground or air monitor, with positive communication with the operators controlling the cloud generator, to physically track the downwind edge of the cloud should also be used during major use and/or if the cloud is drifting near a reservation boundary or civilian-use areas.

(d) Individuals with respiratory conditions, including histories of asthma or cardiac conditions, severe facial acne, or any active dermatitis should be evaluated by a medical officer before being allowed to participate in smoke field training. Preventive masking procedures specified by Forces Command (FORSCOM) should be followed.

(e) Smoke training areas would be sited to avoid nesting areas of endangered wildlife.

### D. Transportation and Storage.

As previously stated petroleum distillates are purchased from commercial industry in a liquid state. They are shipped in accordance with Title 49, Code of Federal Regulations primarily by trucks in 55-gallon drums. The demand for fog oil has been approximately 6400-6500 drums per year. It is centrally managed by the Defense General Supply Center (DGSC), Richmond, VA. It is then allocated to and stored at five designated Defense Logistics Agency (DLA) storage areas located near the prime user installations in the United States. Diesel fuel on the other hand is purchased by the

Defense Fuel Supply Agency and shipped directly from the supplier to the user. Shipping is handled entirely by the supplier until it reaches the designated site.

All transportation is done in accordance with the regulations in the regulatory section of this report. Storage is in compliance with Title 29, Code of Federal Regulations, Part 1910.106 under OSHA regulations for storage of flammable liquids and under military regulations, AR 200-1 and AMCR 385-100. Site specific SPCC and ISCP (Installation Spill Contingency Plans) further the control and cleanup of possible spills that may occur on post.

When the industry is contracted by the Army to supply services or materials they are required by federal law to comply with guidelines presented in Title 40, Code of Federal Regulations, Part 15 on the administration of the Clean Air Act and Federal Water Pollution Control Act. Furthermore, they are required to comply with any state and local regulations governing the area in which shipping occurs.

Once procured by the Army, impacts that may occur from storage, such as leakage or spillage, will not be major. Since the largest storage containers for these petroleum distillates are primarily 55-gallon drums, spills should result in only local minimal impacts. Spills would be reported immediately as indicated in the Regulatory Section of this report.

#### E. Demil/Disposal Phase.

Diesel fuel, fog oil, and PEG 200 are used until the supply is depleted. Any excesses beyond the requirement for an exercise are returned to storage or disposed of in accordance with DOD 4160.21-M-1 and AR 200-1; as amended and supplemented. State and local requirements that pertain to the disposal of oils are also applied.<sup>19,20,21</sup> Conversely when Army tactical weapons and equipment are no longer useful or becomes obsolete, they are demilitarized in accordance with established Department of Defense (DOD) procedures. Detailed demilitarization and disposal protocols are required for each developmental item before type classification. Demil/disposal procedures for smoke generators are outlined in item specific environmental documents. The US Army Armament, Munitions and Chemical Command (AMCCOM), Maintenance & Defense Ammunitions Directorates are responsible for all demil/disposal of items in accordance with existing directives. Unique disposal problems will be the responsibility of the appropriate AMCCOM directorate to initiate the resolution updating the disposal procedure in order to conform with current disposal standards, techniques, and other influencing conditions.<sup>22</sup>

##### 1. Alternatives Considered.

The decision not to demilitarize or dispose of an item would require storage at individual installation's Defense Property Disposal Office (DPDO). Therefore, there are no alternatives to be considered.

##### 2. Environmental Impacts of Activities.

Barring exposure to lethal chemical agents in a wartime environment, environmental risks associated with typical disposal procedures of oils and smoke generating hardware should be minimal. Most items will be recycled or salvaged, however, those impacts that may occur from disposal, including incineration of waste oils, are maintained within the limits set forth in the previous regulations.

## VI. AGENCIES/PERSONS CONTACTED

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## VII. CONCLUSIONS

In general, the toxicological effects and, by extension, environmental impacts reported from exposure to oil-base, visual screening agents have resulted from either high dose rates (e.g., 7 liters of diesel fuel fed to a cow), or protracted periods of exposure (e.g., CAF, JAX mice exposed to a 100 mg/m<sup>3</sup> aerosol for 6 hr/day, 5 days/wk for 16 months with "equivocal evidence of altered rate of lung tumor formation in this tumor-susceptible species"). This is not to imply that the screening agents are innocuous compounds, for they are not. Potential environmental hazards during field tests and training exercises will be the product of complex interactions between a host of physical, chemical, physiological, and ecological factors and must be examined site specifically. Many hazards and impacts, however, can be easily negated, controlled, or mitigated as discussed in Section V.

If equipment operators take proper precautions to preclude inhalation and topical exposures, then health hazards for operators or test personnel would be cancelled. If tests are conducted in areas remote from civilian dwellings or communities, then public health hazards would be averted. If aquatic systems are avoided, potential impacts would be circumvented; if they can not be avoided, then wind vectors and periods of atmospheric instability could be selected to mitigate impacts. Exercises will be conducted on areas dedicated to military testing and training thus there are no inconsistencies with land-use policies. Most emissions would not release the tremendous quantities of screening agents for the protracted periods of time resulting in dose rates that elicited toxicological symptoms in some laboratory animals. Wind vectors will vary during periods of test, therefore, screening will be diluted. Furthermore, as the models were computed so that downwind concentrations could be interpreted and the STEL and TWA values located downwind, it is shown that these concentrations respectively impact approximately at 560 meters and 900 meters downwind from the XM52 and 3000 meters and 5000 meters downwind from the XM16, making the impacts local in nature (concentrations should be insignificant at this distance downwind). Exposures at each site would be intermittent.

The program will not significantly affect the quality of the human environment. An Environmental Impact Statement is not required and a Finding of No Significant Impact will be published in accordance with Title 40, Code of Federal Regulations, Part 1508.13.

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## **APPENDIX A**

### **Principal World War II Smoke Screening Operations**



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# Appendix A. Principal World War II Smoke Screening Operations

Source: Paul W. Pritchard, "Smoke Generator Operations in the Mediterranean and European Theaters of Operation," Chemical Corps Historical Studies No. 1; Brooks E. Kleber and Dale Bridsell, Chemical Warfare Services: Chemicals in Combat, UNITED STATES ARMY IN WORLD WAR II.

Location	Munitions Used <sup>1</sup>	Duration Operation	Total Time <sup>2</sup> U.S. Generators in Operation	Operating U.S. Smoke Generator Units	Troops Screened or Type of Screen	Fog Oil Expended <sup>3</sup> (gals.)
Oran, Algeria	Br, US Pots; M-1 Gen	9 Nov 42 - 1" Aug 43	(22 Dec 42-27 Jan 43)	69th Cml SG Co.	Port, II Corps	-----
Algiers, Algeria	Br, US Pots, Br Haslar, M-1 Gens	16 Nov 42 - Dec 43	(Jan - Jun 43)	78th, 69th SG Cos.	Port	-----
Bone, Algeria	Br, US Pots; M-1 Gen	20 Apr - 17 Jun 43	353 mins.	69th SG Co.	Port	13,615
Bizerte, Tunisia	"	7 May-Dec 43	396 mins	69th, 78th, 168th, 172d SG Cos.	Port	23,763 (29 Jun- 6 Sep 43)
Palermo, Sicily	US Pots; M-1 Gen	16 Aug 43 - Jun 44	Unknown	69th, 78th SG Cos, 21st Cml Decon Co.	Port	-----
Naples, Italy	Br, US Pots; Br, USN Besler, M-1 Gens	Sep 43-Oct 44	(Sep 43 - May 44 night-time)	78th, 163d, 164th, 168th, 172d, 179th SG Cos, 24th Cml Decon Co.	Port Complex	-----
Salerno, Italy <sup>4</sup>	Br, US Pots; USN Besler, M-1 Gens	9 Sep - 10 Oct 43	(9 Sep-10 Oct 43)	24th Cml Decon Co.	Br 10 Corps, US VI Corps, Port, Tactical Area	5,000 daily (approx.)



Location	Munitions Used <sup>1</sup>	Duration Operation	Total Time <sup>2</sup> U.S. Generators in Operation	Operating U.S. Smoke Generator Units	Troops Screened or Type of Screen	Fog Oil Expended <sup>3</sup> (gals.)
Anzio, Italy <sup>5</sup>	Br, US Pots; USN Besler, M-1 Gens	22 Jan-Jul 44	(22 Jan - Jul 44 night-time -- 18 Mar-Jun 44 day- time)	24th Cml Decon Co, 179th SG Co.	US VI Corps Assault Bea-h, Port, Tactical Area	100, 386 (22 Jan- Jan-1 <sup>st</sup> Mar) 200,000 monthly (approx.) (18 Mar - 30 Jun)
Leghorn, Italy <sup>6</sup>	Br, US Pots; M-1 Gen	28 Jul 44 - Apr 45	(28 Jul-3 Sep 44; 15 hrs per day haze--nightly port screen)	172d, 179th SG Cos.	Port, Tactical Area	-----
Garigliano, Valley	US Pots; M-1 Gen	8 Mar-May 44	(28 Mar-May 44)	172d SG Co.	88th Inf Div <sup>7</sup>	4,000 daily (approx.)
St. Tropez, France	US Pots; Besler Gen	15-16 Aug 44	(15-16 Aug 44)	21st Cml Decon Co.	3d Inf Div	-----
Arnaville, France	US Pots; M-1, M-2 Gens	10 Sep - 8 Nov 44	2,118 hrs	84th, 161st Cos.	XX Corps: 5th Inf Div	100,900
Metz and Saar Valley France and Germany	US Pots; M-1, M-2 Gens	9 Nov - 22 Dec 44	3,826 hrs	84th, 161st Cos.	XX Corps: 5th, 90th, 95th, Inf Divs	191,300
Our, Saar, Moselle River Crossings Germany	US Pots; M-1, M-2 Gens	18 Jan - 17 Mar 45	887 hrs	81st, 161st, 162d, 84th SG Cos.	XII, XX, VIII Corps: 6th & 10th Armed Divs 5th, 76th, 80th, 87th, 89th, 90th, 94th Inf Divs	44,250

Location	Munitions Used <sup>1</sup>	Duration Operation	Total Time <sup>2</sup> U.S. Generators in Operation	Operating U.S. Smoke Generator Units	Troops Screened or Type of Screen	Fog Oil Expended <sup>3</sup> (gals.)
Main and Rhine River Crossings, Germany (3d US Army)	US Pots; M-1, M-2 Gens	22 Mar - 1 Apr 45	2,342 hrs	81st, 84th, 161st, 162d SG Cos.	VIII, XII, XX Corps: 5th, 80th, 87th, 89th, 90th Inf Divs	117,088
Ruhr River Crossing, Germany	Br, US Pots; M-2 Gen	6 Jan - 3 Mar 45	534 hrs	74th, 83d SG Cos.	XIII, XIX Corps: 29th, 30th, 83d, 84th, 102d Inf Divs	28,215
Rhine River Crossing Germany (9th US Army)	Br Pots; M-2 Gen	15-31 Mar 45	1,000 hrs	74th, 83d, 84th SG Co.	XVI Corps: 30th, 75th, 79th Divs	50,000
Rhine River Crossing Germany (1st US Army)	M-2 Gen	17-23 Mar 45	2,477 hrs	23d SG Bn, 79th, 80th SG Cos.	VII Corps: 237th 294th, 297th Engr Combat Bns, 1106th, 1120th Eng Combat Gps	122,950
Meurthe River Crossing, France	USN Besler, M-2 Gens	20 Oct - 5 Dec 44	564 hrs	21st Cml Decon Co, 168th SG Co.	VI Corps: 3d, 36th, 103d Inf Divs	29,444
Colmar Pocket	M-1, M-2, USN Besler Gens; US Pots	23 Jan - 21 Feb 45	21,450	21st Cml Decon Co, 168th, 69th, SG Cos.	VI, XXI Corps: 3d, 36th Inf Divs	139,184

Location	Munitions Used <sup>1</sup>	Duration Operation	Total Time <sup>2</sup> U.S. Generators in Operation	Operating U.S. Smoke Generator Units	Troops Screened or Type of Screen	Fog Oil Expended <sup>3</sup> (gals.)
Blies, Moder, Zintzel, Saar River Crossings, Germany	US Pots; M-1, M-2 Gens	17 Feb - 24 Mar 45	25 hrs	69th, 78th, 163d, 168th SG Cos.	VI, XV Corps: 3d, 36th, 71st Inf Divs	1,300
Rhine River Crossing, Germany (7th US Army)	US Pots; M-1, M-2 Gens	25 Mar - 6 Apr 45	340 hrs	69th, 78th, 163d, 168th SG Cos.	XV Corps: 3d, 36th, 71st Inf Divs	16,330
Main, Neckar, Danube River Crossings, Germany	US Pots; M-1, M-2 Gens	31 Mar - 30 Apr 45	2,491 hrs	69th, 163d, 168th SG Cos.	VI, XV, XXI Corps: 3d, 42d, 100th Inf Divs	149,585
Marshall Islands	US Pots; USN Besler Gens.	Jan - ? 1944	Unknown	US Navy	Anchorage	Unknown
Saipan, Marianas	"	15 Jun - 7 Jul 44	19 hrs	"	"	57,000
Leyte, P.I.	US Pots; USN Besler M-2 Gens.	20 Oct-? 44	Unknown	"	Anchorage, Assault Beach	Unknown
Lingayen Gulf, P.I.	"	Jan - ? 45	"	"	"	"



Location	Munitions Used <sup>1</sup>	Duration Operation	Total Time <sup>2</sup> U.S. Generators in Operation	Operating U.S. Smoke Generator Units	Troops Screened or Type of Screen	Fog Oil Expended <sup>3</sup> (gals.)
Iwo Jima	"	?	(16 Air raids)	"	Anchorage	"
Okinawa	US Pots; USN Besler M-2 Gens	1 Apr - 21 Jun 45	(1 Apr-21 Jun 45 est. 188 hrs)	"	Anchorage, Assault and Landing Beaches	2,475,000 est.

Notes: 1. Br. Pot - British Mark 24 Smoke Generator (actually a chemical mix pot). US Pots - M-1, M-4, M-5 HC Smoke pots. M-1 Gen, M-1 Mechanical Smoke Generator using Fog Oil. M-2 Gen - M-2 Mechanical Smoke Generator using Fog Oil. Besler Gen - Mechanical Smoke Generator employed by US Navy and British using Fog Oil. Haslar Gen - A large smudge pot-type British generator.

2. Exact or estimated time of operation given when known. Dates in parenthesis are inclusive dates of mechanical smoke generator employment. Dates not included in this column but indicated in column 3 were those on which only pot screens were made.

3. Estimated when basis for estimation exists. Sometimes compiled from incomplete information.

4. Location of the first employment of a World War II tactical screen.

5. Tactical haze screen first developed and used at Anzio. Also represents the first extensive daylight operation.

6. Both haze and port screens employed at Leghorn.

7. All Mediterranean and European screens hereafter were tactical area screens and usually haze screens.

**Blank**

## **APPENDIX B**

### **Properties and Regulations Governing Petroleum Distillates**



**Blank**

<b>Common Synonyms</b> Kerosene Lamp oil JP-1	Watery liquid Colorless Kerosene odor Flots on water
Strip discharge if possible Call fire department Avoid contact with liquid Isolate and remove discharged material Notify local health and pollution control agencies	
<b>Fire</b>	Combustible. Extinguish with dry chemical, foam or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.
<b>Exposure</b>	<b>CALL FOR MEDICAL AID.</b> <b>LIQUID</b> Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. <b>DO NOT INDUCE VOMITING.</b>
<b>Water Pollution</b>	Dangerous to aquatic life in high concentrations. Floating to shoreline. May be dangerous if it enters water intake. Notify local health and wildlife officials. Notify operators of nearby water intake.
<b>1. RESPONSE TO DISCHARGE</b> <small>(See Response Methods Handbook, CG 446-1)</small> Mechanical containment Should be removed Chemical and physical treatment	<b>2. LABELS</b> No hazard label required by Code of Federal Regulations
<b>3. CHEMICAL DESIGNATIONS</b> 3.1 Synonyms: JP-1 Kerosene Aerosine Range oil 3.2 Coast Guard Compatibility Classification: Miscellaneous hydrocarbon mixtures 3.3 Chemical Formula: Not applicable 3.4 IMCO/United Nations Numerical Designation: 3.3/1223	<b>4. OBSERVABLE CHARACTERISTICS</b> 4.1 Physical State (as shipped): Liquid 4.2 Color: Colorless to light brown 4.3 Odor: Characteristic
<b>5. HEALTH HAZARDS</b> 5.1 Personal Protective Equipment: Protective gloves, goggles or face shield 5.2 Symptoms Following Exposure: INGESTION causes irritation of gastrointestinal tract, pulmonary tract irritation secondary to exhalation of vapors, ASPIRATION causes severe lung irritation with coughing, gagging, dyspnea, substernal distress, and rapidly developing pulmonary edema, signs of bronchopneumonia and pneumonia appear later; minimal central nervous system depression 5.3 Treatment for Exposure: INGESTION do NOT lavage or induce vomiting, call physician. ASPIRATION, enforce bed rest, administer oxygen, call physician. EYES wash with plenty of water. SKIN wipe off and wash with soap and water. 5.4 Toxicity by Inhalation (Threshold Limit Value): 200 ppm (suggested) 5.5 Short-Term Inhalation Limits: Data not available 5.6 Toxicity by Ingestion: Grade I, LD <sub>50</sub> 5-15 g/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary. 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain may cause smarting or reddening of the skin. 5.10 Odor Threshold: 1 ppm	

**6. FIRE HAZARDS**

- 6.1 Flash Point: 100°F C C  
 6.2 Flammable Limits in Air: 0.7% - 5%  
 6.3 Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide  
 6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective  
 6.5 Special Hazards of Combustion Products: Not pertinent  
 6.6 Behavior in Fire: Not pertinent  
 6.7 Ignition Temperature: 444°F  
 6.8 Electrical Hazard: Not pertinent  
 6.9 Burning Rate: 4 mm/min

**8. WATER POLLUTION**

- 8.1 Aquatic Toxicity: 2400 ppm/24 hr. (slug)/171 m/fresh water  
 8.2 Waterway Toxicity: Data not available  
 8.3 Biological Oxygen Demand (BOD): 5% 5 days  
 8.4 Food Chain Concentration Potential: None

**9. SELECTED MANUFACTURERS**

- Atlantic Richfield  
717 Fifth Ave.  
New York, N. Y. 10022
- Shell Oil Co.  
1 Shell Plaza  
Houston, Tex. 77001
- Sun Oil Co.  
St. Davids, Pa. 19087

**10. SHIPPING INFORMATION**

- 10.1 Grades or Purities: Light hydrocarbon distillate; 100%  
 10.2 Storage Temperature: Ambient  
 10.3 Inert Atmosphere: No requirement  
 10.4 Venting: Open (flame arrester)

**11. HAZARD ASSESSMENT CODE**

(See Hazard Assessment Handbook, CG 446-3)  
 A-T-U

**12. HAZARD CLASSIFICATIONS**

- 12.1 Code of Federal Regulations: Combustible Liquid  
 12.2 HAS Hazard Rating for Bulk Water Transportation:
- | Category                 | Rating |
|--------------------------|--------|
| Fire                     | 2      |
| Health                   |        |
| Vapor Irritant           | 1      |
| Liquid or Solid Irritant | 1      |
| Poisons                  | 1      |
| Water Pollution          |        |
| Human Toxicity           | 1      |
| Aquatic Toxicity         | 1      |
| Aesthetic Effect         | 3      |
| Reactivity               |        |
| Other Chemicals          | 0      |
| Water                    | 0      |
| Self-Reaction            | 0      |
- 12.3 NFPA Hazard Classifications:
- | Category             | Classification |
|----------------------|----------------|
| Health Hazard (Blue) | 0              |
| Flammability (Red)   | 2              |
| Reactivity (Yellow)  | 0              |

**13. PHYSICAL AND CHEMICAL PROPERTIES**

- 13.1 Physical State at 15°C and 1 atm: Liquid  
 13.2 Molecular Weight: Not pertinent  
 13.3 Boiling Point at 1 atm: 380 - 540°F  
                                   = 193 - 293°C = 466 - 566°K  
 13.4 Freezing Point: -45 to -55°F  
                                   = -43 to -48°C = 230 to 225°K  
 13.5 Critical Temperature: Not pertinent  
 13.6 Critical Pressure: Not pertinent  
 13.7 Specific Gravity: 0.81 - 0.85 at 15°C (liquid)  
 13.8 Liquid Surface Tension: 23 - 32 dynes/cm  
                                   = 0.023 - 0.032 N/m at 20°C  
 13.9 Liquid-Water Interfacial Tension: 47 - 49 dynes/cm = 0.047 - 0.049 N/m at 20°C  
 13.10 Vapor (Gas) Specific Gravity: Not pertinent  
 13.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent  
 13.12 Latent Heat of Vaporization: 110 Btu/lb = 60 cal/g = 2.5 x 10<sup>3</sup> J/kg  
 13.13 Heat of Combustion: -18,540 Btu/lb  
                                   = -10,300 cal/g = -431.24 x 10<sup>3</sup> J/kg  
 13.14 Heat of Decomposition: Not pertinent  
 13.15 Heat of Solution: Not pertinent  
 13.16 Heat of Polymerization: Not pertinent

(Continued on pages 1 and 6.)

**NOTES**

Common Synonyms Crankcase oil Transmission oil Motor oil	Oily liquid Yellow-brown Late oil odor Flashes on water
Stop discharge if possible Call fire department Avoid contact with liquid Isolate and remove discharged material Notify local health and pollution control agencies	
<b>Fire</b>	Combustible Extinguish with dry chemical, foam or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water
<b>Exposure</b>	CALL FOR MEDICAL AID. <b>LIQUID</b> Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
<b>Water Pollution</b>	Effect of low concentrations on aquatic life is unknown. Floating to shoreline. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.
<b>1. RESPONSE TO DISCHARGE</b> <small>(See Response Methods Handbook, CG 446-1)</small> Mechanical containment Should be removed Chemical and physical treatment	<b>2. LABELS</b> No hazard label required by Code of Federal Regulations
<b>3. CHEMICAL DESIGNATIONS</b> 3.1 Synonyms: Crankcase oil Motor oil Transmission oil 3.2 Coast Guard Compatibility Classification: Miscellaneous hydrocarbon mixtures 3.3 Chemical Formula: Not applicable 3.4 IMCO/United Nations Numerical Designation: 3.3/1270	<b>4. OBSERVABLE CHARACTERISTICS</b> 4.1 Physical State (as shipped): Liquid 4.2 Color: Yellow fluorescent 4.3 Odor: Characteristic
<b>5. HEALTH HAZARDS</b> 5.1 Personal Protective Equipment: Protective gloves, goggles or face shield 5.2 Symptoms Following Exposure: INGESTION: minimal gastrointestinal tract irritation, increased frequency of bowel passage may occur. ASPIRATION: pulmonary irritation is normally minimal but may become more severe several hours after exposure 5.3 Treatment for Exposure: INGESTION: do NOT lavage or induce vomiting. ASPIRATION: treatment probably not required, delayed development of pulmonary irritation can be detected by serial chest x-rays. EYES: wash with copious quantity of water. SKIN: wipe off and wash with soap and water 5.4 Toxicity by Inhalation (Threshold Limit Value): Data not available 5.5 Short-Term Inhalation Limit: Data not available 5.6 Toxicity by Ingestion: Grade I, LD50 15 g/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin 5.10 Odor Threshold: Data not available	

<b>6. FIRE HAZARDS</b> 6.1 Flash Point: 300°-450°F C/C 6.2 Flammable Limits in Air: Data not available 6.3 Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide 6.4 Fire Extinguishing Agents Not to be Used: Water or foam may cause frothing 6.5 Special Hazards of Combustion Products: Not pertinent 6.6 Behavior in Fire: Not pertinent 6.7 Ignition Temperature: 500°F 700°F 6.8 Electrical Hazard: Not pertinent 6.9 Burning Rate: 4 mm/min	<b>8. WATER POLLUTION</b> 8.1 Aquatic Toxicity: Data not available 8.2 Waterfowl Toxicity: Data not available 8.3 Biological Oxygen Demand (BOD): Data not available 8.4 Food Chain Concentration Potential: None								
<b>7. CHEMICAL REACTIVITY</b> 7.1 Reactivity with Water: No reaction 7.2 Reactivity with Common Materials: No reaction 7.3 Stability During Transport: Stable 7.4 Neutralizing Agents for Acids and Caustics: Not pertinent 7.5 Polymerization: Not pertinent 7.6 Inhibitor of Polymerization: Not pertinent	<b>9. SELECTED MANUFACTURERS</b> 1. Shell Oil Co 1 Shell Plaza Houston, Tex. 77001 2. Standard Oil Co (Indiana) 910 S. Michigan Ave Chicago, Ill. 60605 3. Sun Oil Co St. Davids, Pa. 19087								
<b>11. HAZARD ASSESSMENT CODE</b> <small>(See Hazard Assessment Handbook, CG 446-3)</small> A-T-U	<b>10. SHIPPING INFORMATION</b> 10.1 Grades or Purities: Various viscosities 10.2 Storage Temperature: Ambient 10.3 Inert Atmosphere: No requirement 10.4 Venting: Open (flame arrester)								
<b>12. HAZARD CLASSIFICATIONS</b> 12.1 Code of Federal Regulations: Not listed 12.2 NAB Hazard Rating for Bulk Water Transportation: Not listed 12.3 NFPA Hazard Classifications: <table data-bbox="879 1412 1135 1509"> <thead> <tr> <th>Category</th><th>Classification</th></tr> </thead> <tbody> <tr> <td>Health Hazard (Blue)</td><td>0</td></tr> <tr> <td>Flammability (Red)</td><td>1</td></tr> <tr> <td>Reactivity (Yellow)</td><td>0</td></tr> </tbody> </table>	Category	Classification	Health Hazard (Blue)	0	Flammability (Red)	1	Reactivity (Yellow)	0	<b>13. PHYSICAL AND CHEMICAL PROPERTIES</b> 13.1 Physical State at 15°C and 1 atm: Liquid 13.2 Molecular Weight: Not pertinent 13.3 Boiling Point at 1 atm: Very high 13.4 Freezing Point: Not pertinent 13.5 Critical Temperature: Not pertinent 13.6 Critical Pressure: Not pertinent 13.7 Specific Gravity: (est.) 0.902 at 20°C (liquid) 13.8 Liquid Surface Tension: 36-37.5 dynes/cm = 0.036-0.0375 N/m at 20°C 13.9 Liquid-Water Interfacial Tension: 33-54 dynes/cm = 0.033-0.054 N/m at 20°C 13.10 Vapor (Gas) Specific Gravity: Not pertinent 13.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent 13.12 Latent Heat of Vaporization: Not pertinent 13.13 Heat of Combustion: -18,486 Btu/lb = -10,270 cal/g = -429 WU x 10 <sup>3</sup> J/kg 13.14 Heat of Decomposition: Not pertinent 13.15 Heat of Solution: Not pertinent 13.16 Heat of Polymerization: Not pertinent
Category	Classification								
Health Hazard (Blue)	0								
Flammability (Red)	1								
Reactivity (Yellow)	0								
NOTES									

(Continued on pages 1 and 6)

Common Synonyms Fuel oil 1-D Fuel oil 2-D		Oily liquid	Yellow-brown	Lubricating oil odor
		Flammable		
Stop discharge if possible Call fire department Avoid contact with liquid Isolate and remove discharged material Notify local health and pollution control agencies				
<b>Fire</b>		Combustible. Extinguish with dry chemical, foam, or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water		
<b>Exposure</b>		CALL FOR MEDICAL AID. LIQUID Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.		
<b>Water Pollution</b>		Dangerous to aquatic life in high concentrations. Feeding to shellfish. May be dangerous if it enters water intakes. Notify local health and wildlife officials Notify operators of nearby water intakes		
<b>1. RESPONSE TO DISCHARGE</b> (See Response Methods Handbook, CG 446-4) Mechanical containment Should be removed Chemical and physical treatment		<b>2. LABELS</b> No hazard label required by Code of Federal Regulations		
<b>3. CHEMICAL DESIGNATIONS</b> 3.1 Synonyms: Fuel Oil 1-D Fuel Oil 2-D 3.2 Coast Guard Competibility Classification: Miscellaneous hydrocarbon mixtures 3.3 Chemical Formula: Not applicable 3.4 IMCO/United Nations Numerical Designation: 311270		<b>4. OBSERVABLE CHARACTERISTICS</b> 4.1 Physical State (as shipped): Liquid 4.2 Color: Light brown 4.3 Odor: Like fuel oil		
<b>5. HEALTH HAZARDS</b> 5.1 Personal Protective Equipment: Goggles or face shield 5.2 Symptoms Following Exposure: If liquid is ingested, an increased frequency of bowel movements will occur 5.3 Treatment for Exposure: INGESTION: do NOT induce vomiting. SKIN: wipe off, wash with soap and water. EYES: wash with copious amounts of water for at least 15 min. 5.4 Toxicity by Inhalation (Threshold Limit Value): No single TLV applicable 5.5 Short-Term Inhalation Limits: Data not available 5.6 Toxicity by Ingestion: Grade I, LD <sub>50</sub> 5 to 15 g/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or respiratory system if present in high concentration. The effect is temporary 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin 5.10 Odor Threshold: Data not available				

<p><b>6. FIRE HAZARDS</b></p> <p>6.1 <b>Flash Point:</b> (1-D) 100°F C.C. (2-D) 125°F C.C.</p> <p>6.2 <b>Flammable Limits in Air:</b> 1.3-6.0 vol %</p> <p>6.3 <b>Fire Extinguishing Agents:</b> Dry chemical, foam, or carbon dioxide</p> <p>6.4 <b>Fire Extinguishing Agents Not to be Used:</b> Water may be ineffective</p> <p>6.5 <b>Special Hazards of Combustion Products:</b> Not pertinent</p> <p>6.6 <b>Behavior in Fire:</b> Not pertinent</p> <p>6.7 <b>Ignition Temperature:</b> (1-D) 350-625°F (2-D) 490-545°F</p> <p>6.8 <b>Electrical Hazard:</b> Not pertinent</p> <p>6.9 <b>Burning Rate:</b> 4 mm/min</p>	<p><b>8. WATER POLLUTION</b></p> <p>8.1 <b>Aquatic Toxicity:</b> 204 mg/l/24 hr/juvenile American shad/ 71 m/salt water</p> <p>8.2 <b>Waterfowl Toxicity:</b> &gt; 20 ml/kg /LD50/mallards</p> <p>8.3 <b>Biological Oxygen Demand (BOD):</b> Data not available</p> <p>8.4 <b>Food Chain Concentration Potential:</b> None</p>								
<p><b>7. CHEMICAL REACTIVITY</b></p> <p>7.1 <b>Reactivity with Water:</b> No reaction</p> <p>7.2 <b>Reactivity with Common Materials:</b> No reaction</p> <p>7.3 <b>Stability During Transport:</b> Stable</p> <p>7.4 <b>Neutralizing Agents for Acids and Caustics:</b> Not pertinent</p> <p>7.5 <b>Polymerization:</b> Not pertinent</p> <p>7.6 <b>Inhibitor of Polymerization:</b> Not pertinent</p>	<p><b>9. SELECTED MANUFACTURERS</b></p> <p>1. Exxon Co. Houston, Tex. 77001</p> <p>2. Shell Oil Co. 1 Shell Plaza Houston, Tex. 77001</p> <p>3. Sun Oil Co. St. Davids, Pa. 19087</p>								
<p><b>11. HAZARD ASSESSMENT CODE</b> (See Hazard Assessment Handbook, CG 448-3) A-T-U</p>	<p><b>10. SHIPPING INFORMATION</b></p> <p>10.1 <b>Grades or Purity:</b> Diesel Fuel 1-D (ASTM); Diesel Fuel 2-D (ASTM)</p> <p>10.2 <b>Storage Temperature:</b> Ambient</p> <p>10.3 <b>Inert Atmosphere:</b> No requirement</p> <p>10.4 <b>Venting:</b> Open (flame arrester)</p>								
<p><b>12. HAZARD CLASSIFICATIONS</b></p> <p>12.1 <b>Code of Federal Regulations:</b> Combustible liquid</p> <p>12.2 <b>NAS Hazard Rating for Bulk Water Transportation:</b> Not listed</p> <p>12.3 <b>NIHA Hazard Classifications:</b></p> <table> <tr> <th>Category</th><th>Classification</th></tr> <tr> <td>Health Hazard (Blue) .....</td><td>0</td></tr> <tr> <td>Flammability (Red) .....</td><td>2</td></tr> <tr> <td>Reactivity (Yellow) .....</td><td>0</td></tr> </table>	Category	Classification	Health Hazard (Blue) .....	0	Flammability (Red) .....	2	Reactivity (Yellow) .....	0	<p><b>13. PHYSICAL AND CHEMICAL PROPERTIES</b></p> <p>13.1 <b>Physical State at 15°C and 1 atm:</b> Liquid</p> <p>13.2 <b>Molecular Weight:</b> Not pertinent</p> <p>13.3 <b>Boiling Point at 1 atm:</b> 550-640°F = 288-338°C = 561-612°K</p> <p>13.4 <b>Freezing Point:</b> 0 to -30°F = -18 to -34°C = 255 to 239°K</p> <p>13.5 <b>Critical Temperature:</b> Not pertinent</p> <p>13.6 <b>Critical Pressure:</b> Not pertinent</p> <p>13.7 <b>Specific Gravity:</b> 0.841 at 16°C (liquid)</p> <p>13.8 <b>Liquid Surface Tension:</b> (test) 25 dyne/cm = 0.024 N/m at 20°C</p> <p>13.9 <b>Liquid-Water Interfacial Tension:</b> (test) 50 dyne/cm = 0.05 N/m at 20°C</p> <p>13.10 <b>Vapor (Gas) Specific Gravity:</b> Not pertinent</p> <p>13.11 <b>Ratio of Specific Heats of Vapor (Gas):</b> Not pertinent</p> <p>13.12 <b>Latent Heat of Vaporization:</b> Not pertinent</p> <p>13.13 <b>Heat of Combustion:</b> -18,400 Btu/lb = -10,200 cal/g = 429 x 10<sup>3</sup> J/kg</p> <p>13.14 <b>Heat of Decomposition:</b> Not pertinent</p> <p>13.15 <b>Heat of Solution:</b> Not pertinent</p> <p>13.16 <b>Heat of Polymerization:</b> Not pertinent</p>
Category	Classification								
Health Hazard (Blue) .....	0								
Flammability (Red) .....	2								
Reactivity (Yellow) .....	0								

<b>Common Synonyms</b> Diesel oil (light)		Oily liquid Yellow-brown Lubric or fuel oil odor
Stop discharge if possible. Call fire department. Avoid contact with liquid. Isolate and remove discharged material. Notify local health and pollution control agencies.		Floats on water
<b>Fire</b>		Combustible. Extinguish with dry chemical, foam or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.
<b>Exposure</b>		CALL FOR MEDICAL AID. <b>LIQUID</b> Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
<b>Water Pollution</b>		Dangerous to aquatic life in high concentrations. Floating to shorelines. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.
<b>1. RESPONSE TO DISCHARGE</b> <small>(See Response Methods Handbook, CG 446-4)</small> Mechanical containment Should be removed Chemical and physical treatment		<b>2. LABELS</b> No hazard label required by Code of Federal Regulations
<b>3. CHEMICAL DESIGNATIONS</b> 3.1 Synonyms: Diesel oil, light 3.2 Coast Guard Compatibility Classification: Miscellaneous hydrocarbon mixtures 3.3 Chemical Formula: Not applicable 3.4 IMCO/United Nations Numerical Designation: 3 1/1270		<b>4. OBSERVABLE CHARACTERISTICS</b> 4.1 Physical State (as shipped): Liquid 4.2 Color: Light brown 4.3 Odor: Characteristic
<b>5. HEALTH HAZARDS</b> 5.1 Personal Protective Equipment: Protective gloves, goggles or face shield 5.2 Symptoms Following Exposure: INHALATION causes headache and slight dizziness. INGESTION causes nausea, vomiting, and cramping, depression of central nervous system ranging from mild headache to anesthesia, coma, and death, pulmonary irritation secondary to inhalation of solvent, signs of kidney and liver damage may be delayed. ASPIRATION causes severe lung irritation with coughing, gagging, dyspnea, substernal distress, and rapidly developing pulmonary edema, later, signs of bronchopneumonia and pneumonia, acute onset of central nervous system excitement followed by depression. 5.3 Treatment for Exposure: INGESTION do NOT induce vomiting, seek medical attention. ASPIRATION enforce bed rest, administer oxygen. EYES wash with copious quantities of water. SKIN remove solvent by wiping and wash with soap and water. 5.4 Toxicity by Inhalation (Threshold Limit Value): No single value applicable 5.5 Short-Term Inhalation Limits: Data not available 5.6 Toxicity by Ingestion: Grade I, LD <sub>50</sub> 5-15 g/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Slight smarting of eyes or respiratory system if present in high concentration. The effect is temporary. 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of skin. 5.10 Odor Threshold: 0.7 ppm		

<div>6. FIRE HAZARDS</div> <div><div>6.1 Flash Point: 100°F (38°C)</div><div>6.2 Flammable Limits in Air: 1.3% - 8%</div><div>6.3 Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide</div><div>6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective</div><div>6.5 Special Hazards of Combustion Products: Not pertinent</div><div>6.6 Behavior in Fire: Not pertinent</div><div>6.7 Ignition Temperature: 350-625°F</div><div>6.8 Electrical Hazard: Not pertinent</div><div>6.9 Burning Rate: 4 mm/min</div></div>	<div>8. WATER POLLUTION</div> <div><div>8.1 Aquatic Toxicity: 214 mg/l/24 hr/juvenile American shad 11 mg/salt water</div><div>8.2 Waterfowl Toxicity: 20 mg/kg LD<sub>50</sub> (mallards)</div><div>8.3 Biological Oxygen Demand (BOD): Data not available</div><div>8.4 Food Chain Concentration Potential: None</div></div>								
<div>7. CHEMICAL REACTIVITY</div> <div><div>7.1 Reactivity with Water: No reaction</div><div>7.2 Reactivity with Common Materials: No reaction</div><div>7.3 Stability During Transport: Stable</div><div>7.4 Neutralizing Agents for Acids and Caustics: Not pertinent</div><div>7.5 Polymerization: Not pertinent</div><div>7.6 Inhibitor of Polymerization: Not pertinent</div></div>	<div>9. SELECTED MANUFACTURERS</div> <div><div>1 Atlantic Richfield Co. 717 Fifth Ave New York, N. Y. 10022</div><div>2 Shell Oil Co 1 Shell Plaza Houston, Tex. 77001</div><div>3 Sun Oil Co. St. Davids, Pa. 19087</div></div>								
	<div>10. SHIPPING INFORMATION</div> <div><div>10.1 Grades or Purity: Diesel fuel I-D (ASTM)</div><div>10.2 Storage Temperature: Ambient</div><div>10.3 Inert Atmosphere: No requirement</div><div>10.4 Venting: Open (flame arrester)</div></div>								
<div>11. HAZARD ASSESSMENT CODE</div> <div>(See Hazard Assessment Handbook, CG 446-3)</div> <div>A-T-U</div>	<div>13. PHYSICAL AND CHEMICAL PROPERTIES</div> <div><div>13.1 Physical State at 15°C and 1 atm: Liquid</div><div>13.2 Molecular Weight: Not pertinent</div><div>13.3 Boiling Point at 1 atm: 380-560°F = 193-293°C = 466-566°K</div><div>13.4 Freezing Point: -30°F = -34°C = 240°K</div><div>13.5 Critical Temperature: Not pertinent</div><div>13.6 Critical Pressure: Not pertinent</div><div>13.7 Specific Gravity: 0.81-0.85 at 15°C (liquid)</div><div>13.8 Liquid Surface Tension: 23-32 dynes/cm = 0.023-0.032 N/m at 20°C</div><div>13.9 Liquid-Water Interfacial Tension: 47-49 dynes/cm = 0.047-0.049 N/m at 20°C</div><div>13.10 Vapor (Gas) Specific Gravity: Not pertinent</div><div>13.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent</div><div>13.12 Latent Heat of Vaporization: 110 Btu/lb = 60 cal/g = 2.5 × 10<sup>5</sup> J/kg</div><div>13.13 Heat of Combustion: -18,540 Btu/lb = -10,300 cal/g = -431.24 × 10<sup>3</sup> J/kg</div><div>13.14 Heat of Decomposition: Not pertinent</div><div>13.15 Heat of Solution: Not pertinent</div><div>13.16 Heat of Polymerization: Not pertinent</div></div>								
<div>12. HAZARD CLASSIFICATIONS</div> <div><div>12.1 Code of Federal Regulations: Combustible Liquid</div><div>12.2 NAS Hazard Rating for Bulk Water Transportation: Not listed</div><div>12.3 NFPA Hazard Classifications:</div><table><thead><tr><th>Category</th><th>Classification</th></tr></thead><tbody><tr><td>Health Hazard (Blue)</td><td>0</td></tr><tr><td>Flammability (Red)</td><td>2</td></tr><tr><td>Reactivity (Yellow)</td><td>0</td></tr></tbody></table></div>	Category	Classification	Health Hazard (Blue)	0	Flammability (Red)	2	Reactivity (Yellow)	0	
Category	Classification								
Health Hazard (Blue)	0								
Flammability (Red)	2								
Reactivity (Yellow)	0								
<div>(Continued on pages 5 and 6)</div>									
<div>NOTES</div>									



<b>Common Synonyms</b> Diesel oil, medium	Oily liquid      Yellow-brown      Lubricant or fuel oil odor  Floats on water
Stop discharge if possible. Call fire department. Avoid contact with liquid. Isolate and remove discharged material. Notify local health and pollution control agencies.	
<b>Fire</b>	Combustible. Extinguish with dry chemical, foam, carbon dioxide. Water may be ineffective on fire. Seal exposed containers with water.
<b>Exposure</b>	<b>CALL FOR MEDICAL AID</b> <b>LIQUID</b> Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED, and victim is CONSCIOUS, have victim drink water or milk. <b>DO NOT INDUCE VOMITING.</b>
<b>Water Pollution</b>	Dangerous to aquatic life in high concentrations. Floating to shoreline. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.
<b>1. RESPONSE TO DISCHARGE</b> (See Response Methods Handbook, CO 446-1) Mechanical containment Should be removed Chemical and physical treatment	
<b>2. LABELS</b> No hazard label required by Code of Federal Regulations	
<b>3. CHEMICAL DESIGNATIONS</b> 3.1 Synonyms: Diesel oil, medium 3.2 Coast Guard Compatibility Classification: Miscellaneous hydrocarbon mixtures 3.3 Chemical Formula: Not applicable 3.4 HCS/United Nations Numerical Designation: 311270	<b>4. OBSERVABLE CHARACTERISTICS</b> 4.1 Physical State (as shipped): Liquid 4.2 Color: Light brown 4.3 Odor: Characteristic, like kerosene
<b>5. HEALTH HAZARDS</b> 5.1 Personal Protective Equipment: Protective gloves, goggles or face shield 5.2 Symptoms Following Exposure: INGESTION causes nausea, vomiting, and cramping; depression of central nervous system ranging from mild headache to anesthesia, coma, and death; pulmonary irritation secondary to exhalation of solvent; signs of kidney and liver damage may be delayed. ASPIRATION causes severe lung irritation with coughing, gagging, dyspnea, subcutaneous distress, and rapidly developing pulmonary edema; later, signs of bronchopneumonia and pneumonitis, acute onset of central nervous system excitement followed by depression 5.3 Treatment for Exposure: INGESTION: do NOT induce vomiting. ASPIRATION: enforce bed rest, administer oxygen, seek medical attention. EYES: wash with copious quantity of water. SKIN: remove solvent by wiping and wash with soap and water 5.4 Toxicity by Inhalation (Threshold Limit Value): No single TLV applicable 5.5 Short-Term Inhalation Limit: Data not available 5.6 Toxicity by Ingestion: Grade 1, LD <sub>50</sub> 4-15 g/kg 5.7 Late Toxicity: Data not available 5.8 Vapor (Gas) Irritant Characteristics: Slight smarting of eyes or respiratory system if present in high concentrations. The effect is temporary 5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of skin 5.10 Odor Threshold: Data not available	

<div>6. FIRE HAZARDS</div> <div><div>6.1 Flash Point: 125°F C.C.</div><div>6.2 Flammable Limits in Air: 1.3% - 6.0%</div><div>6.3 Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide</div><div>6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective</div><div>6.5 Special Hazards of Combustion Products: Not pertinent</div><div>6.6 Behavior in Fire: Not pertinent</div><div>6.7 Ignition Temperature: 490-545°F</div><div>6.8 Electrical Hazard: Not pertinent</div><div>6.9 Burning Rate: 4 mm/min</div></div>	<div>8. WATER POLLUTION</div> <div><div>8.1 Aquatic Toxicity: 204 mg/l/24 hr/juvenile American shad TL<sub>50</sub> salt water</div><div>8.2 Waterfowl Toxicity: Data not available</div><div>8.3 Biological Oxygen Demand (BOD): Data not available</div><div>8.4 Food Chain Concentration Potential: None</div></div>								
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<div>12. HAZARD CLASSIFICATIONS</div> <div><div>12.1 Code of Federal Regulations: Combustible Liquid</div><div>12.2 HAS Hazard Rating for Bulk Water Transportation: Not listed</div><div>12.3 NFPA Hazard Classifications:</div><table><thead><tr><th>Category</th><th>Classification</th></tr></thead><tbody><tr><td>Health Hazard (Blue)</td><td>0</td></tr><tr><td>Flammability (Red)</td><td>2</td></tr><tr><td>Reactivity (Yellow)</td><td>0</td></tr></tbody></table></div>	Category	Classification	Health Hazard (Blue)	0	Flammability (Red)	2	Reactivity (Yellow)	0	
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Health Hazard (Blue)	0								
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1C (continued on pages 5 and 6)

NOTES

(Continued on pages 5 and 6)

MIL-F-12070B  
16 June 1982  
SUPERSEDING  
MIL-F-12070A  
10 May 1956

## MILITARY SPECIFICATION

### FOG OIL

This specification is approved for use by all  
Departments and Agencies of the Department of Defense.

#### 1. SCOPE

1.1 Scope. This specification covers two types of fog oil.

1.2 Classification. Fog oil shall be of the following types as specified  
(see 6.2):

Type SGF1 - For use above 40°F  
Type SGF2 - For use at 40°F or lower

#### 2. APPLICABLE DOCUMENTS

##### 2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified,  
the following specifications, standards, and handbooks of the issue listed in  
that issue of the Department of Defense Index of Specifications and Standards  
(DoDISS) specified in the solicitation form a part of this specification to the  
extent specified herein.

#### STANDARDS

##### MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by  
Attributes  
MIL-STD-290 - Packaging of Petroleum and Related Products

FSC 9150

: Beneficial comments (recommendations, additions, deletions) and any perti- :  
: nent data which may be of use in improving this document should be addressed :  
: to: Commander, US Army Armament Research and Development Command, ATTN: :  
: DRDAR-TSC-S, Aberdeen Proving Ground, MD 21010 by using the self-addressed :  
: Standardization Document Improvement Proposal (DD Form 1426) appearing at :  
: the end of this document or by letter. :

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.

#### UNIFORM FREIGHT CLASSIFICATION RULES

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

#### ASTM STANDARDS

- D99 - Saybolt Viscosity
- D92 - Flash and Fire Points by Cleveland Open Cup
- D97 - Pour Point of Petroleum Oils
- D974 - Neutralization Number by Color-Indicator Titration
- D1160 - Distillation of Petroleum Products at Reduced Pressures

(Application for copies should be addressed to ASTM, 1916 Race Street, Philadelphia, PA 19103.)

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

### 3. REQUIREMENTS

3.1 Material. ~~The fog oil shall be an overhead petroleum fraction and shall contain no additives.~~ The contractor shall certify that this requirement has been met.

3.2 Appearance. ~~The fog oil shall be free from water, sediment, suspended particles, grit, and other foreign matter when tested as specified in 4.2.4.1.~~

3.3 Chemical and physical characteristics. ~~The fog oil shall conform to the applicable chemical and physical characteristics of table I when tested as specified therein.~~

TABLE I. Chemical and physical characteristics

Characteristic	Type SGF1		Type SGF2		Test paragraph:
	Min	Max	Min	Max	
Flash point, °F	400		320		4.2.4.2
Viscosity, Saybolt Universal					4.2.4.3
At 100°F, seconds			100	110	
At 210°F, seconds		55			
Neutralization number		0.1		0.1	4.2.4.4
Pour point, °F		0		-40	4.2.4.5
Vapor temperature, °F at					4.2.4.6
10 percent distilled	390				
50 percent distilled	490				
90 percent distilled		610			

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

#### 4.2 Quality conformance inspection.

4.2.1 Lotting. A lot shall consist of the fog oil of one type produced by one manufacturer, at one plant, from the same materials, and under essentially the same manufacturing conditions provided the operation is continuous. In the event the process is a batch operation, each batch shall constitute a lot (see 6.3).

#### 4.2.2 Sampling.

4.2.2.1 For examination of packaging. Sampling shall be conducted in accordance with MIL-STD-105.

4.2.2.2 For test. Sampling shall be conducted in accordance with table II. A representative specimen of approximately 1 liter shall be removed from each sample container and placed in a suitable clean, dry container labeled to identify the lot and container from which it was taken.

TABLE II. Sampling for test

<u>: Number of containers in batch or lot : Number of sample containers :</u>	
:	:
: 2 to 25	: 2
: 26 to 150	: 3
: 151 to 1,200	: 5
: 1,201 to 7,000	: 8
: Over 7,001	: 13
:	:

#### 4.2.3 Inspection procedure.

4.2.3.1 For examination of packaging. The sample unit shall be one filled shipping container ready for shipment. Sample shipping containers shall be examined for the following defects grouped collectively using an AQL of 4.0 per cent defective:

- (a) Contents per container not as specified
- (b) Container not as specified
- (c) Container closure not as specified
- (d) Container damaged or leaking
- (e) Marking incorrect, missing, or illegible

4.2.3.2 For test. Each sample specimen taken in 4.2.2.2 shall be tested as specified in 4.2.4. Failure of any test by any specimen shall be cause for rejection of the lot represented.

#### 4.2.4 Tests. Tests shall be conducted as follows:

4.2.4.1 Appearance. Visually examine the specimen for water, sediment, suspended particles, grit, and other foreign matter.

4.2.4.2 Flash point. Determine the flash point of the specimen in accordance with ASTM D92.

4.2.4.3 Viscosity. Determine the Saybolt Universal viscosity of the specimen in accordance with ASTM D88.

4.2.4.4 Neutralization number. Determine the neutralization number of the specimen in accordance with ASTM D974.

4.2.4.5 Pour point. Determine the pour point of the specimen in accordance with ASTM D97.

MIL-F-12070B

4.2.4.6 Vapor temperature. Determine the vapor temperatures of the specimen at 10, 30, and 90 percents by volume distilled in accordance with ASTM D1160 using a distillation pressure of  $10.0 \pm 0.2$  millimeters of mercury absolute.

5. PACKAGING

5.1 Unit packing. Fog oil shall be unit packed level A, B, or C as specified (see 6.2).

5.1.1 Level A. A quantity of 55 (+0.5 or -0) US gallons of fog oil shall be unit packed in a drum having clean and dry interior and exterior surfaces. The drum shall conform to Uniform Freight Classification Rule 40 for other than dry or solid articles and shall be formed from low carbon steel sheet having a minimum thickness of 16 gauge. Each drum shall be furnished with a nominal 2-inch filler plug and a nominal 3/4-inch vent plug with flanges and gaskets located diametrically opposite the top head. The exterior of the drum shall be coated with baked-on, weather-resistant, color forest green enamel. Plugs on filled drums shall be closed to a torque recommended by the drum manufacturer.

5.1.2 Level B. A quantity of 55 (+0.5 or -0) US gallons of fog oil shall be level B unit packed in accordance with MIL-STD-290.

5.1.3 Level C. Fog oil shall be level C unit packed in accordance with MIL-STD-290.

5.2 Packing. Fog oil unit packed as specified in 5.1 shall require no further protection for shipment.

5.3 Marking. Containers shall be marked in accordance with MIL-STD-290 and shall show date of fog oil manufacture and lot number.

6. NOTES

6.1 Intended use. Fog oil is intended for use in mechanical smoke generators.

6.2 Ordering data. Acquisition documents should specify the following:

- (a) Title, number, and date of this specification
- (b) Type of fog oil required (see 1.2)
- (c) Level of unit packing required (see 5.1)

6.3 Batch. A batch is defined as that quantity of material which has been manufactured by some unit chemical process or subjected to some physical mixing operation intended to make the final product substantially uniform.

MIL-F-12070B

**Custodians:**

Army - EA

Navy - SH

**Review activities:**

Navy - OS, SA

DLA - GS, PS

**Preparing activity:**

Army - EA

Project No. 9150-0426

VV-F-800C  
September 15, 1980  
SUPERSEDING  
Fed. Spec. VV-F-800B  
April 2, 1975

## FEDERAL SPECIFICATION

### FUEL OIL, DIESEL

This specification was approved by the Commissioner, Federal Supply Service, General Services Administrator for the use of all Federal Agencies.

#### 1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers diesel fuel oils suitable for use in automotive diesel and/or compression-ignition engines and gas turbine engines other than aircraft under all climatic conditions (see 6.1).

1.2 Classification. The diesel fuel oils shall be of three grades, as follows:

<u>Military Symbol</u>	<u>NATO Code No.</u>	<u>Description</u>
DF-A	--	Arctic grade
DF-1	--	Winter grade
DF-2	F-54	Regular grade

#### 2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein:

##### Federal Standards:

Fed. Test Method Std. No. 791 - Lubricants, Liquid Fuels, and Related Products; Methods of Testing.

(Activities outside the Federal Government may obtain copies of Federal specifications, standards and commercial item descriptions as outlined under General Information in the Index of Federal Specifications, Standards and Commercial Item Descriptions. The Index, which includes cumulative bimonthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FSC 9140



(Single copies of this specification and other Federal specifications, standards and commercial item descriptions required by activities outside the Federal Government for bidding purposes are available without charge from General Services Administration Business Service Centers in Boston; New York; Philadelphia; Washington, DC; Atlanta; Chicago; Kansas City, MO; Fort Worth; Houston; Denver; San Francisco; Los Angeles; and Seattle, WA.

(Federal Government activities may obtain copies of Federal specifications, standards and commercial item descriptions and the Index of Federal Specifications, Standards and Commercial Item Descriptions from established distribution points in their agencies.)

**Military Specifications:**

- MIL-I-25017 - Inhibitor, Corrosion, Fuel Soluble.
- MIL-I-27686 - Inhibitor, Fuel System Icing.

**Military Standards:**

- MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
- MIL-STD-290 - Packaging, Packing, and Marking of Petroleum and Related Products.

**Military Qualified Products List:**

- QPL-25017 - Inhibitor, Corrosion, Fuel Soluble.

(Copies of Military Specifications and Standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

**2.2 Other publications.** The following documents form a part of this specification to the extent specified herein. Unless a specific issue is identified, the issue in effect on date of invitation for bids or request for proposal shall apply.

**American Society for Testing and Materials Publications:**

- D 86 - Distillation of Petroleum Products
- D 93 - Flash Point by Pensky-Martens Closed Tester
- D 97 - Pour Point
- D 129 - Sulfur in Petroleum Products by the Bomb Method
- D 130 - Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test
- D 270 - Sampling Petroleum and Petroleum Products
- D 445 - Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)
- D 482 - Ash from Petroleum Products
- D 524 - Ramsbottom Carbon Residue of Petroleum Products
- D 613 - Ignition Quality of Diesel Fuels by the Cetane Method
- D 974 - Neutralization Number by Color-Indicator Titration

D 976	- Calculated Cetane Index of Distillate Fuels
D 1298	- Density, Specific Gravity or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D 1552	- Sulfur in Petroleum Products (High-Temperature Method)
D 2274	- Stability of Distillate Fuel Oil (Accelerated Method)
D 2276	- Particulate Contaminant in Aviation Turbine Fuels
D 2500	- Cloud Point of Petroleum Oils
D 2622	- Sulfur in Petroleum Products (X-Ray Spectrographic Method)

(Most of the ASTM Methods listed above are included in various Parts of the Annual Book of ASTM Standards and are available individually. ASTM Method D 613 is available only in the ASTM Manual for Rating Motor, Diesel, and Aviation Fuels. Application for copies of all ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street Philadelphia, PA 19103.)

### 3. REQUIREMENTS

**3.1 Material.** The diesel fuels supplied under this specification shall be refined petroleum distillates. Additive agents, such as stabilizers, pour point depressants, haze improvers, flow improvers, etc., will be permitted for products purchased by individual installations in the continental U.S. (CONUS). However, for military bulk deliveries outside the continental U.S. (CONUS), or long term storage (greater than six months) applications (i.e., Army depot facilities, stand-by power generators), only those additives specified in 3.2 will be permitted.

**3.2 Additives.** The additives listed herein may be used in amounts not to exceed those specified.

**3.2.1 Antioxidants.** The following active inhibitors may be blended separately or in combination into the fuel in a total concentration of 8.4 pounds of inhibitor (not including weight of solvent) per 1,000 barrels of fuel (9.1 g/100 gal (US), 24 mg/liter or 109 mg/gal (UK)) in order to prevent the formation of gum:

- (a) N,N' -diisopropyl-para-phenylenediamine
- (b) N,N' -dissecondary butyl-par-phenylenediamine
- (c) 2,6-ditertiary butyl-4-methylphenol
- (d) 6-tertiary butyl-2,4-dimethylphenol
- (e) 2,6-ditertiary butylphenol
- (f) 75 percent min. 2,6-ditertiary butylphenol and 25 percent max. tertiary and tritertiary butylphenols
- (g) 60 percent min. 2,4-ditertiary butylphenol and 40 percent max. mixed tertiary butylphenols

**3.2.2 Cetane improvers.** The cetane number requirements specified in table I may be obtained by use of any one or any combination of the approved cetane improvers (amyl nitrate, isopropyl nitrate, hexyl nitrate, cyclohexyl nitrate, 2-ethylhexyl nitrate, and octyl nitrate).

- (a) For grade DF-A - 0.25 percent by weight  
 (b) For grade DA-1 and DF-2 - 0.50 percent by weight

3.2.3 Corrosion inhibitors. A corrosion inhibitor conforming to MIL-I-25017 may be blended into the fuel by the contractor. The amount added shall be equal to or greater than the minimum effective concentration and shall not exceed the maximum allowable concentration listed in the latest revision of QPL-25017.

3.2.4 Fuel system icing-inhibitor. A fuel system icing inhibitor conforming to MIL-I-27686 (NATO Code S-748) may be blended into the fuel in an amount not to exceed 0.15 percent by volume.

3.3 Physical and chemical requirements. The diesel fuels shall conform to the requirements specified in table I and 3.4.

TABLE I. Physical and chemical requirements.

Properties	Values			
	Grade DF-A	Grade DF-1	Grade DF-2:	
			CONUS	OCONUS
Density, kg/L @15°C	Report	Report	Report	0.815 to 0.860
Flash point, °C min.	38	38	52	56 <sup>1/</sup>
Cloud point, °C max.	-51	2/	2/	2/
Pour point, °C max.	Report	Report	Report	3/
Kinematic viscosity @40°C (20°C), cSt	1.1 to 2.4	1.3 to 2.9	1.9 to 4.1	(1.8 to 9.5)
Distillation, °C:				
50% evaporated	Report	Report	Report	Report
90% evaporated, max.	288	288	338	357
End point, max.	300	330	370	370
Residue, vol. %, max.	3	3	3	3
Carbon residue on 10% bottoms, mass %, max. <sup>4/</sup>	0.10	0.15	.35	.20
Sulfur, mass %, max.	0.25	0.50	0.50	0.70
Copper strip corrosion, 3 hrs. @ 50° C				
max. rating	3	3	3	1
Ash, mass %, max.	0.01	0.01	0.01	0.02
Accelerated stability, total insolubles mg/100 mL, max. <sup>5/</sup>	1.5	1.5	1.5	1.5
Neutralization number, TAN, max.	0.05	--	--	0.10
Particulate contamination, mg/liter, max.	10	10	10	10
Cetane number, min.	40	45	45	45

- 1/ DF-2 intended for entry into the Central European Pipeline System shall have a minimum value of 58°C.
- 2/ As specified by the procuring activity based on guidance in Appendix A. DF-2 for Europe and S. Korea shall have a maximum limit of minus 13°C.
- 3/ As specified by the procuring activity. DF-2 for Europe and S. Korea shall have a maximum limit of minus 18°C.
- 4/ See Appendix B. If the fuel contains cetane improvers, the test must be performed on the base fuel blend only.
- 5/ This requirement is applicable only for military bulk deliveries intended for tactical, OCONUS, or long term storage (greater than six months) applications (i.e., Army depots, etc.).

3.4 Workmanship. The finished diesel fuels shall be visually free from undissolved water, sediment and suspended matter and shall be clear and bright at the ambient temperature or 70°F (21°C), whichever is higher.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

#### 4.2 Lot.

4.2.1 Bulk lot. An indefinite quantity of a homogeneous blend of diesel fuel of one grade offered for acceptance in a single isolated container; or manufactured in a single plant run (not exceeding 24 hours) through the same processing equipment, with no change in ingredient material.

4.2.2 Packaged lot. An indefinite number of 55-gallon drums or other unit containers of identical size and type, offered for acceptance, and filled with a homogeneous blend of diesel fuel of one grade from one isolated container; or filled with a homogeneous blend of diesel fuel of one grade manufactured in a single plant run (not exceeding 24 hours) through the same processing equipment, with no change in ingredient material.

#### 4.3 Sampling.

4.3.1 Sampling for the inspection of filled containers. Take a random sample of filled containers from each lot in accordance with MIL-STD-103, at inspection level II and acceptable quality level (AQL) = 2.5 percent defective.

4.3.2 Sampling for tests. Take samples for tests in accordance with ASTM Method D 270. Test the samples in accordance with 4.6.

4.4 Inspection. Perform inspection in accordance with Method 9601 of Fed. Test Method Std. No. 791.

4.4.1 Examination of the preparation for delivery. Examine samples taken in accordance with 4.3.1 for compliance with MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and marking requirements. Reject any container having one or more defects or under the required fill. Reject the lot represented by the sample if the number of defective or underfilled containers exceeds the acceptance number for the appropriate sampling plan of MIL-STD-105.

4.5 Classification of tests. All tests are quality conformance tests.

4.6 Test methods. Perform tests in accordance with the applicable methods listed in table II and Appendix B.

TABLE II. Test methods.

Test	Test Method No.
Density	ASTM D 1298
Flash point	ASTM D 93
Cloud point	ASTM D 2500
Pour point	ASTM D 97
Kinematic viscosity	ASTM D 445
Distillation	ASTM D 86
Carbon residue <sup>1/</sup>	ASTM D 524
Sulfur <sup>2/</sup>	ASTM D 1552, D 129, or D 2622
Copper strip corrosion	ASTM D 130
Ash	ASTM D 482
Accelerated stability	ASTM D 2274
Neutralization	ASTM D 974
Particulate contamination	ASTM D 2276 (Appendix A2)
Cetane number <sup>3/</sup>	ASTM D 613 or D 976
Fuel system icing inhibitor	Fed. Test Method Std. No. 791, Methods 5327, 5330, or 5340

<sup>1/</sup> See Appendix B.

<sup>2/</sup> D 1552 is the preferred method but D 129 and D 2622 may be used as an alternate.

<sup>3/</sup> D 613 is the preferred method for determining cetane quality. However, where cetane improvers have not been used as determined by Appendix B, D 976 may be used as an alternate.

## 5. PREPARATION FOR DELIVERY

**5.1 Packaging, packing, and marking.** Unless otherwise specified in the contract or order (see 6.2), packaging, packing, and marking shall be in accordance with MIL-STD-290.

## 6. NOTES

### 6.1 Intended use.

**6.1.1 Military symbol DF-A.** Arctic-grade diesel fuel oil is intended for use in high-speed automotive-type diesel engines, gas turbine engines other than air-craft, and pot-type burner space-heaters, in areas where ambient temperatures lower than  $-32^{\circ}\text{C}$  generally occur, and where it is impractical to maintain dual storage capabilities. This grade of diesel fuel should not be used for slow-speed stationary engine applications.

**6.1.2 Military symbol DF-1.** Winter-grade diesel fuel oil is intended for use in high-speed automotive diesel engines and gas turbine engines other than air-craft, in areas in which ambient temperatures as low as  $-32^{\circ}\text{C}$  may occur (see Appendix A). This grade of diesel fuel may be used for medium-speed stationary engine applications, where fuel heating facilities are not available.

**6.1.3 Military symbol DF-2.** Regular-grade diesel fuel oil is intended for use in all automotive high-speed/medium-speed engine applications and gas turbine engines other than aircraft, in temperate climates according to guidelines in Appendix A.

**6.2 Ordering data.** Purchasers should select the preferred options offered herein and include the following information in procurement documents:

- (a) Title, number, and date of this specification.
- (b) Grade designation (military symbol; see 1.2).
- (c) Size and type container required (see 5.1).
- (d) Quantity of diesel fuel required. The unit of purchase is the U.S. gallon (231 cubic inches at  $60^{\circ}\text{F}$  ( $15.6^{\circ}\text{C}$ )).
- (e) Level of packaging and level of packing required (see 5.1).
- (f) Cloud point for DF-1 and DF-2 (see Appendix A).
- (g) Pour point for OCONUS DF-2 (see note 3, table I).

**6.3** Certain provisions of this specification are the subject of international standardization agreements (NATO STANAGS 1135, 2754, and 2845). When amendment, revision, or cancellation of this specification is proposed which would affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental standardization offices, if required.

**VV-F-800C**

**MILITARY INTEREST:**

**Custodians:**

Army - ME

Navy - SH

Air Force - 68

**Review activities:**

Army - AT

Navy - YD, SA

Air Force - 11

**User activities**

Army - GL, MI

**CIVIL AGENCY COORDINATING ACTIVITIES:**

GSA - PSS

DOT - MVP

COMMERCE - NBS

HEW - FEC, NIH

**Preparing Activity:**

Army - ME

Project 9140-0098

## APPENDIX A

## TENTH PERCENTILE MINIMUM AMBIENT TEMPERATURE FOR DEFINING SATISFACTORY LOW TEMPERATURE PROPERTIES OF DIESEL FUEL.

## 10. SCOPE

10.1 This appendix covers a method to assess the low temperature operability limit for automotive diesel fuel.

## 20. METHODOLOGY

20.1 Minimum daily temperatures compiled from weather stations were statistically evaluated to determine the probability for various temperature occurrences. A method of reporting this probability is with the use of percentiles which evaluate the compiled distribution and report the temperatures corresponding to their probabilities of occurrence. To predict limiting low ambient temperatures, the 10th percentile minimum temperature values have been selected as a realistic guide. By definition, the 10th percentile minimum temperature predicts a 10 percent chance that the daily minimum will be lower than the predicted value, or a 90 percent chance that the daily minimum will be no lower than the predicted value.

## 30. APPLICATION

30.1 The 10th percentile minimum temperature values for the United States and OCONUS areas are tabulated and presented in table III and IV. Satisfactory operation should be achieved in most cases if the Cloud Point is specified at or below the 10th percentile minimum temperature. This guidance is of a general nature as some equipment design, use of flow improvers, fuel properties, and/or type of operating conditions may allow higher or require lower cloud point fuels.



TABLE III. United States 10th percentile minimum temperatures, °C.

State	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Alabama	13	4	-3	-6	-7	-3	-2
Alaska: 1/							
Northern	-7	-25	-37	-45	-49	-47	-42
Southern	-1	-11	-13	-18	-32	-32	-29
South East	1	-4	-11	-16	-19	-13	-12
Arizona:							
N 34° LAT	1	-4	-12	-14	-17	-16	-12
S 34° LAT	13	7	0	-2	-4	-3	-1
Arkansas	9	2	-4	-7	-11	-7	-3
California: 2/							
N and S Coast	6	4	0	-2	-2	-1	-1
Interior and SE	6	1	-6	-8	-11	-7	-6
Colorado:							
E 105° LONG	4	-2	-12	-14	-19	-15	-12
W 105° LONG	-3	-8	-18	-25	-30	-24	-16
Connecticut	4	-1	-7	-16	-17	-16	-9
Delaware	8	2	-3	-10	-11	-10	-5
Florida	17	7	1	-1	-3	-1	4
Georgia	12	3	-2	-6	-7	-6	-2
Idaho	2	-4	-13	-18	-21	-18	-13
Illinois	5	-1	-9	-19	-21	-18	-11
Indiana	6	-1	-7	-16	-18	-16	-9
Iowa	4	-2	-13	-23	-26	-22	-16
Kansas	4	-2	-11	-15	-19	-14	-13
Kentucky	7	1	-6	-13	-14	-11	-6
Louisiana	14	5	-1	-3	-4	-2	1
Maine	1	-3	-10	-23	-26	-26	-18
Maryland	8	2	-3	-10	-12	-10	-4
Massachusetts	3	-2	-7	-16	-18	-17	-10
Michigan	1	-2	-11	-20	-23	-23	-18
Minnesota	-1	-4	-18	-30	-34	-31	-24
Mississippi	13	3	-3	-6	-6	-4	-1
Missouri	8	1	-7	-14	-16	-13	-8
Montana	-1	-7	-18	-24	-30	-24	-21
Nebraska	3	-3	-13	-18	-22	-19	-13
Nevada:							
N 38° LAT	-2	-7	-14	-17	-22	-18	-13
S 38° LAT	14	8	0	-3	-4	-2	1
New Hampshire	1	-3	-8	-18	-21	-21	-12
New Jersey	8	2	-3	-11	-12	-11	-6
New Mexico	5	-2	-11	-14	-17	-14	-11
New York	1	-3	-8	-21	-24	-24	-16
North Carolina	6	-1	-7	-10	-11	-9	-5
North Dakota	1	-4	-20	-27	-31	-29	-22
Ohio	4	-1	-7	-16	-17	-15	-9

TABLE III. United States 10th percentile minimum temperatures, °C. (Cont'd)

State	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Oklahoma	9	1	-8	-12	-13	-8	-7
Oregon:							
E 122° LONG	-1	-6	-11	-14	-19	-21	-9
W 122° LONG	4	0	-4	-5	-7	-4	-3
Pennsylvania	0	-3	-8	-19	-20	-21	-15
Rhode Island	6	1	-3	-12	-13	-13	-7
South Carolina	13	5	-1	-5	-5	-3	-2
South Dakota	3	-4	-14	-24	-27	-24	-18
Tennessee	7	1	-5	-9	-11	-9	-4
Texas:							
N 31° LAT	9	3	-6	-9	-13	-9	-7
S 31° LAT	16	9	2	-2	-3	-1	2
Utah	4	-2	-11	-14	-18	-14	-8
Vermont	3	-3	-8	-20	-23	-24	-15
Virginia	8	2	-3	-9	-11	-9	-4
Washington:							
E 122° LONG	2	-2	-8	-11	-18	-11	-8
W 122° LONG	3	0	-3	-3	-7	-4	-3
West Virginia	3	-3	-8	-15	-16	-14	-9
Wisconsin	2	-3	-14	-24	-28	-24	-18
Wyoming	1	-4	-15	-18	-26	-19	-16

1/ Details of state division are as indicated:

- \* Northern Region: Area north of the 62° LAT.
- \* Southern Region: Area bordered on the north by the 62° LAT, bordered on the east by the 141° LONG., and bordered on the south by the 56° LAT.
- \* Southeastern Coast and Aleutian Islands: Area bordered on the north by Canada, bordered on the west by the 141° LONG., and the remaining area bordered on the north by the 56° LAT.

2/ Details of state division by county as indicated:

- California, North Coast - Alameda, Contra Costa, Del Norte, Humboldt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, Trinity
- California, Interior - Alpine, Amador, Butte, Calaveras, Colusa, El Dorado, Fresno, Glenn, Kern (except that portion lying east of the Los Angeles County Aqueduct), Kings, Lassen, Madera, Mariposa, Merced, Modoc, Nevada, Placer, Plumas, Sacramento, San Joaquin, Shasta, Sierra, Siskiyou, Stanislaus, Sutter, Tehama, Tulare, Tuolumne, Yolo, Yuba

California, South Coast - Los Angeles (except that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura

California, Southeast - Imperial, Inyo, Kern (that portion lying east of the Los Angeles County Aqueduct), Los Angeles (that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Mono, Riverside, San Bernardino

TABLE IV. OCONUS 10th percentile minimum temperatures, ° C.

Country	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Austria	-1	-5	-12	-10	-9	-6	-1
Belgium	0	-3	-9	-7	-6	-6	-3
Denmark	-1	-3	-6	-7	-7	-7	-3
France	0	-2	-9	-9	-5	-5	-1
Germany	-2	-5	-13	-13	-12	-9	-5
Greece	5	0	-3	-3	-2	-1	3
Iceland	-1	-5	-7	-9	-7	-7	-4
Italy	1	-3	-6	-8	-7	-3	-1
Korea	1	-6	-13	-20	-15	-7	-1
Luxembourg	1	-3	-7	-7	-6	-4	-2
Netherlands	0	-2	-8	-8	-6	-5	-2
Norway	-6	-14	-16	-18	-18	-16	-6
Portugal	8	4	1	1	1	1	5
Turkey	-1	-6	-10	-16	-16	-6	-1

## APPENDIX B

## DETECTION OF NITRATE-TYPE IGNITION IMPROVERS IN DIESEL FUEL

## 10. SCOPE

10.1 This method of test covers the determination of organic nitrate ester-type cetane improver additives used in diesel fuel. It is intended as a screening test for those diesel fuel inspection test procedures that are affected by the presence of cetane improvers; namely, ASTM D 524 Standard Method of Test for Rambottom Carbon Residue of Petroleum Products and D 976 Standard Methods for Calculated Cetane Index of Distillate Fuels.

## 20. SUMMARY

20.1 A diesel fuel sample is saponified in a potassium hydroxide-1 butanol mixture and then filtered through a glass fiber filter disk. The material remaining on the disc is treated with diphenylamine reagent after drying. The presence of a nitrate ester cetane improver is revealed by the formation of a blue ring and/or blue-black spot due to oxidation of diphenylamine to intense blue quinoidal compounds by the nitrate salt. No color change confirms the absence of a cetane improver.

## 30. APPARATUS

30.1 Reaction bottle - Screw-cap bottle, 29.6 mL (1 fl oz) capacity, wide mouth, flint glass, with screw cap lined with tin or tetrafluoroethylene (TFE) resin.

30.2 Glass fiber filter paper - 37 mm diameter, Grade 934 AH (H. Reeve Angel, Inc., Clifton, N. J., or equivalent).

30.3 Pipette - 10 mL capacity, fitted with a pipetting bulb. Several types and makes of pipetting bulbs and assemblies are available. One of the following is suggested: Fisher Cat. No. 13-681, Pipet Filler, Fisher Safety, or equal; Fisher Cat. No. 13-681-50, Pipet Filler, or equal; Fisher Cat. No. 13-682, Pipet Adapter, Fisher, or equal.

30.4 Graduated cylinders - 10 mL and 25 mL capacity.

30.5 Suction flask with a suitable holder to accommodate a 60 mL glass-fitted crucible.

30.6 Crucible - 60 mL capacity, glass-fritted, medium porosity.

30.7 Oven suitable for drying filter discs at 110° C.

#### 40. REAGENTS

40.1 Saponification mixture (1n) - Prepared by mixing 6.5 g potassium hydroxide (ACS grade) with 100 mL absolute 1-butanol (ACS grade) and heating to dissolve the KOH. After the solution cools, the mixture is filtered through the glass fiber filter paper.

40.2 Diphenylamine (1 percent solution) - Prepared by dissolving 0.250 g diphenylamine (ACS indicator grade) in 25 mL sulfuric acid (sp. gr. 1.834).

40.3 Toluene (ACS reagent grade).

NOTE: Toluene is flammable and toxic. Avoid breathing vapors or contact with skin.

#### 50. PROCEDURE

50.1 Pipette 10 mL of sample into the reaction bottle and add 5 mL of toluene followed by 10 mL of the saponification mixture.

NOTE: Oral pipetting techniques should not be used because of the toxicity of the substances involved. A pipetting bulb or assembly similar to one of those described in 30.3 should be used.

50.2 Affix cap to the reaction bottle tightly and, after mixing the contents, place it in an oven maintained at 110° C for 4 hours.

50.3 Remove the reaction bottle from the oven and allow it to cool to 25° ± 3°C.

50.4 Filter the contents of the reaction bottle through the 60 mL glass fritted crucible fitted with the glass filter disc.

50.5 Wash the reaction bottle with 25 mL of toluene and transfer it to the glass-fritted crucible.

50.6 Carefully remove the glass fiber filter disc and dry it in oven at 110°C for 15 minutes.

50.7 Remove the filter disc and cool it to 25° ± 3°C.

50.8 Add 3 drops of diphenylamine solution to the center of the disc and observe whether a blue or blue-black color forms.

#### 60. REPORT

60.1 The presence of organic nitrate ester-type cetane improvers will be reported if the formation of a blue color occurs. Reference samples of diesel fuels containing 0.5 percent by volume of any one of the approved cetane

improvers (amyl nitrate, cyclohexyl nitrate, hexyl nitrate, isopropyl nitrate, 2-ethylhexyl nitrate, and octyl nitrate) give an intense blue to blue-black color throughout the reagent spot whereas those samples containing only 0.1 percent by volume produce a blue ring at the outer boundary of the reagent. If a positive reaction occurs (i.e., a blue or blue-black coloration), the carbon residue determination (d 524) must be performed on a neat or base fuel blend.

U.S. GOVERNMENT PRINTING OFFICE : 1981 - 341-705/1189

Orders for this publication are to be placed with General Services Administration, acting as an agent for the Superintendent of Documents. See section 2 of this specification to obtain extra copies and other documents referenced herein.

MIL-F-46162B(ME)  
14 August 1981  
SUPERSEDING  
MIL-F-46162A(MR)  
6 April 1976

## MILITARY SPECIFICATION

### FUEL, DIESEL, REFEREE GRADE

This specification is approved for use by the Mobility Equipment Research and Development Command, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

#### 1. SCOPE

1.1 Scope. This specification covers one grade of diesel fuel for use in research, development and proof testing of all compression-ignition engines, diesel-powered auxiliary units, gas turbine engine driven ground vehicles and mobile electric power generators, and other fuel handling supply items designed to operate with tactical grades of diesel fuel conforming to VV-F-800 (see 6.1).

1.2 Definition. Referee grade is defined as follows:

Referee grade diesel fuel. A diesel fuel representing the minimal or marginal quality level which can be procured under specification VV-F-800 while meeting all of its requirements. It is designed to be equivalent to the quality of OCONUS distillate production or that production available in times of national emergency. It is used for research, development and proof testing to assure that all diesel-consuming equipment will perform adequately with all diesel fuels procured under VV-F-800.

#### 2. APPLICABLE DOCUMENTS

##### 2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified (see 6.2), the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation, form a part of this specification to the extent specified herein.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Mobility Equipment Research and Development Command, ATTN: DRDME-DS, Fort Belvoir, VA 22060 by using the self-addressed Standardization Document Improvement Proposal (DP Form 1426) appearing at the end of this document or by letter.

FSC 9140

## SPECIFICATIONS

### FEDERAL

VV-F-800

- Fuel Oil, Diesel.

### MILITARY

MIL-T-5624

MIL-I-25017

MIL-T-83133

- Turbine Fuel, Aviation, Grades JP-4 and JP-5.  
- Inhibitor, Corrosion, Fuel Soluble.  
- Turbine Fuel, Aviation, Kerosine Type, Grade JP-8.

## STANDARDS

### FEDERAL

FED-STD-791

- Lubricants, Liquid Fuels and Related Products; Methods of Testing.

### MILITARY

MIL-STD-105

MIL-STD-290

- Sampling Procedures and Tables for Inspection by Attributes.  
- Packaging, Packing and Marking of Petroleum and Related Products.

## QUALIFIED PRODUCTS LISTS

### MILITARY

QPL-25017

- Qualified Products List of Products Qualified Under Military Specification MIL-I-25017.

(Copies of specifications, standards, drawings and publications required by manufacturers in connection with specific procurement functions should be obtained from the acquisition activity or as directed by the contracting officer.)

2.1.2 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.



## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS

- D 86 - Distillation of Petroleum Products.
- D 93 - Flash Point by Pensky-Martens Closed Tester.
- D 97 - Pour Point of Petroleum Oils.
- D 129 - Sulfur in Petroleum Products (General Bomb Method).
- D 130 - Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test.
- D 240 - Heat of Combustion of Liquid Hydrocarbon Fuels (General Bomb Method).
- D 270 - Sampling Petroleum and Petroleum Products.
- D 287 - API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method).
- D 445 - Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity).
- D 482 - Ash from Petroleum Products.
- D 524 - Ramsbottom Carbon Residue of Petroleum Products.
- D 613 - Ignition Quality of Diesel Fuels by the Cetane Method.
- D 974 - Neutralization Number by Color-Indicator Titration.
- D 976 - Calculated Cetane Index of Distillate Fuels.
- D 1319 - Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption.
- D 1552 - Sulfur in Petroleum Products (High Temperature Method).
- D 2274 - Stability of Distillate Fuel Oil (Accelerated Method).
- D 2276 - Particulate Contaminant in Aviation Turbine Fuels.
- D 2500 - Cloud Point of Petroleum Oils.
- D 2622 - Sulfur in Petroleum Products (X-Ray Spectrographic Method).

(The test methods listed above are included in Parts 23, 24, 25 and in other Parts of the Annual Book of ASTM Standards and are available individually. ASTM Method D 613 is available only in the ASTM Manual for Rating Motor, Diesel and Aviation Fuels. Applications for copies of all ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Specifications and standards of technical societies are generally available for reference from libraries. They are also distributed among interested Federal agencies.)

### 3. REQUIREMENTS

3.1 Material. The diesel fuels shall be refined petroleum distillates. Those fuels meeting the requirements shall contain catalytically or thermally processed blending fractions with additives as specified in 3.2 and its subparagraphs.

3.2 Additives. Additive use shall be as specified in 3.2.1, 3.2.2, 3.2.3 and 3.2.4. Addition of an antioxidant or stabilizer and a corrosion inhibitor is mandatory. Addition of a cetane improver(s) or a pour-point depressant or flow

improver is permissible, if necessary to meet requirements of this specification. The particular additives and the amounts used shall be limited to those specified.

**3.2.1 Antioxidants and stabilizers.** Any one or a combination of the following oxidation inhibitors shall be blended into the fuel in a total concentration of 8.4 pounds of inhibitor (not including the weight of solvent) per 1000 barrels (42 gal/bbl) of fuel (9.1 g/100 gal (US), 24 mg/liter, or 109 mg/gal (UK), to prevent the formation of gum:

- (a) N,N'-diisopropyl-para-phenylenediamine.
- (b) N,N'-disecodary butyl-para-phenylenediamine.
- (c) 2,6-ditertiary butyl-4-methylphenol.
- (d) 2,4-dimethyl-6-tertiary butylphenol.
- (e) 2,6-ditertiary butylphenol.
- (f) 75 percent min 2,6-ditertiary butylphenol and 25 percent max tertiary and tritertiary butylphenols.
- (g) 60 percent min 2,4-ditertiary butylphenol and 40 percent max mixed tertiary butylphenols.

The addition of antioxidants or stabilizers other than those listed in this paragraph is permitted, provided that prior approval is obtained from the US Army Mobility Equipment Research and Development Command, ATTN: DEDME-GL, Ft. Belvoir, VA 22060. Requests for approval shall contain the chemical name or trade name of the additive, concentration of additive in the fuel, and laboratory data demonstrating the effectiveness of the additive in diesel fuels.

**3.2.2 Corrosion inhibitor.** A corrosion inhibitor conforming to MIL-I-25017 shall be blended into the fuel. The amount added shall be equal to or greater than the minimum effective concentration and shall not exceed the maximum allowable concentration listed in the latest revision of QPL-25017.

**3.2.3 Cetane improver.** The cetane number requirements specified in table I may be obtained by use of any one or any combination of the approved cetane improvers (amyl nitrate, isopropyl nitrate, hexyl nitrate, cyclohexyl nitrate, and octyl nitrate), including the structural isomers of amyl, hexyl, and octyl nitrates. The total concentration of cetane improvers shall not exceed 0.50 percent by weight.

**3.2.4 Pour-point depressant or flow improver.** A pour-point depressant or flow-improver additive may be used to meet the low temperature requirements specified in table I.

**3.3 Physical and chemical requirements.** The diesel fuels shall conform to the requirements specified in table I.

**3.4 Workmanship.** The finished diesel fuel shall be visually free from undissolved water, sediment and suspended matter and shall be clear and bright at 21° C.

TABLE I. Physical and chemical requirements.

Property	Value
Density, Kg/L @ 15° C	Report
Flash point, °C	Report
Cloud point, °C max	-13
Pour point, °C max	-18
Kinematic viscosity, cSt at 40° C	1.9 to 4.1
Distillation, °C:	
Initial boiling point	Report
10% recovered	Report
50% recovered	245 to 285
90% recovered	330 to 357
95% recovered	350 to 375
End point, max	385
Carbon residue on 10% bottoms,	0.20
% wt, max <sup>1/</sup>	
Sulfur, % wt <sup>2/</sup>	0.95 to 1.05
Copper strip corrosion, 3 hrs @	1
50° C, ASTM classification, max	
Ash, % wt, max	0.02
Accelerated stability, total	1.5
insolubles, mg/100 ml, max	
Neutralization No., TAN, max	0.2
Aromatics, volume %	Report
Net heat of combustion, BTU/lb	Report
Particulate contamination,	10
mg/liter, max	
Cetane number	40 to 45

<sup>1/</sup> See Appendix. The maximum limits do not apply for samples containing cetane improvers. In those instances, the test must be performed on the basefuel blend.

<sup>2/</sup> Sulfur in the finished fuel should be naturally-occurring. If additional sulfur is required, only tertiary butyl disulfide shall be added.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

##### 4.2 Lot.

4.2.1 Bulk lot. An indefinite quantity of a homogeneous mixture of one grade of fuel oil offered for acceptance in a single, isolated container; or manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

4.2.2 Packaged lot. An indefinite number of 55 gallon drums or smaller unit containers of identical size and type, offered for acceptance, and filled with a homogeneous mixture of one grade of fuel oil from a single, isolated container; or filled with a homogeneous mixture of one grade of fuel oil, manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

##### 4.3 Sampling.

4.3.1 Sampling for examination of filled containers. Take a random sample of filled containers from each packaged lot in accordance with MIL-STD-105 at inspection level II and acceptable quality level (AQL) = 2.5 percent defective.

4.3.2 Sampling for tests. Take samples for tests in accordance with ASTM Method D 270.

4.4 Inspection. Perform inspection in accordance with Method 9601 of FED-STD-791.

4.4.1 Examination of filled containers. Examine samples taken in accordance with 4.3.1 for compliance with MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and marking requirements. Reject any container having one or more defects or under the required fill. If the number of defective or underfilled containers exceeds the acceptance number for the appropriate plan of MIL-STD-105, reject the lot represented by the sample.

4.5 Classification of tests. All tests are quality conformance tests.

4.6 Test methods. Perform tests in accordance with the applicable methods listed in table II and Appendix.

TABLE II. Test methods.

Test	ASTM Test Method No.
Gravity, °API	D 287
Flash point	D 93
Cloud point	D 2500
Pour point	D 97
Kinematic viscosity	D 445
Distillation	D 86
Carbon residue <sup>1/</sup>	D 524
Sulfur <sup>2/</sup>	D 1552, D 129, or D 2622
Copper strip corrosion	D 130
Ash	D 482
Accelerated stability	D 2274
Neutralization number	D 974
Aromatics	D 1319
Net heat of combustion	D 240
Particulate contamination	D 2276 (Appendix A2)
Cetane number <sup>3/</sup>	D 613 or D 976

<sup>1/</sup> See Appendix.

<sup>2/</sup> D 1552 is the preferred method but either D 129 or D 2622 may be used as an alternate.

<sup>3/</sup> D 613 is the preferred method for determining cetane quality. However, where cetane improvers have not been used as determined by the method in the Appendix, D 976 may be used as an alternate.

4.7 Report of analysis. The contractor shall provide copies of analysis reports, giving the results of these tests with a statement of the types and concentrations of the additives used in the diesel fuel.

## 5. PACKAGING

5.1 Packing and marking. Diesel fuel contained in the size and type container specified (see 6.2), shall be packed and marked in accordance with MIL-STD-290. Packing shall be level A, level B, or commercial as specified (see 6.2).

## 6. NOTES

6.1 Intended use. This diesel fuel is intended for use in research, development and proof-testing of all compression-ignition engines, diesel-powered auxiliary units, gas turbine engine driven ground vehicles and mobile electric power generators, and other fuel handling supply items. The use of referee fuel in conjunction with Development Testing (DTI through DTIII) is considered necessary to uncover potential operational problems with respect to performance and to enable data correlation of all testing sites regardless of geographical location. Referee fuels should not be used in engines or other

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equipment in the field as a substitute for VV-F-800 diesel fuel without approval of the engine manufacturer or from the US Army Mobility Equipment Research and Development Command, ATTN: DRDME-GL, Fort Belvoir, VA 22060.

6.1.1 Temperature range. This diesel fuel is intended for use in all engine and equipment qualification, proof, engineering or pilot model testing where ambient temperatures at or above minus 18° C are anticipated. At temperatures below minus 18° C, JP-8 fuel conforming to MIL-T-83133 or JP-5 fuel conforming to MIL-T-5624 should be used.

6.2 Ordering data.

- (a) Title, number and date of this specification.
- (b) Size and type of container required (see 5.1).
- (c) Degree of packing required (see 5.1).
- (d) Quantity of diesel fuel required. The unit of purchase is the US gallon [231 cubic inches at 60° F (15.6° C)]

Custodian:  
Army - ME

Preparing activity:  
Army - ME

Review activities:  
Army - AT  
DLA - PS

Project 9140-A097

User activities:  
Army - CE, TE

APPENDIX

DETECTION OF NITRATE-TYPE IGNITION IMPROVERS IN DIESEL FUEL

10. SCOPE

10.1 Scope. This method of test covers the determination of organic nitrate ester-type cetane improver additives used in diesel fuel. It is intended as a screening test for those diesel fuel inspection test procedures that are affected by the presence of cetane improvers; namely, ASTM D 524, Ramsbottom Carbon Residue of Petroleum Products and ASTM D 976, Calculated Cetane Index of Distillate Fuels.

20. SUMMARY

20.1 Summary. A diesel fuel sample is saponified in a potassium hydroxide - 1 butanol mixture and then filtered through a glass fiber filter disc. The material remaining on the disc is treated with diphenylamine reagent after drying. The presence of a nitrate ester cetane improver is revealed by the formation of a blue ring or blue-black spot due to oxidation of diphenylamine to intense blue quinoidal compounds by the nitrate salt. No color change confirms the absence of a cetane improver.

30. APPARATUS

30.1 Reaction bottle. Screw-cap bottle, 29.6 ml (1 fl oz) capacity, wide mouth, flint glass, with screw-cap lined with tin or tetrafluorethylene (TFE) resin.

30.2 Glass fiber filter paper. 37-mm diameter, Grade 934 AH (H. Reeve Angel, Inc., Clifton, NJ, or equivalent).

30.3 Pipette. 10-ml capacity, fitted with a pipetting bulb. Several types and makes of pipetting bulbs and assemblies are available. One of the following is suggested: Fisher Cat No. 13-681, Pipet Filler, Fisher Safety, or equal; Fisher Cat No. 13-681-50, Pipet Filler, or equal; Fisher Cat No. 13-682, Pipet Adapter, Fisher or equal.

30.4 Graduated cylinders. 10-ml and 25-ml capacity.

30.5 Suction flask with a suitable holder to accommodate a 60-ml glass-fritted crucible.

30.6 Crucible. 60-ml capacity, glass-fritted, medium porosity.

30.7 Oven. Suitable for drying filter discs at 110° C.

## APPENDIX

## 40. REAGENTS

40.1 Saponification mixture (IN). Prepare by mixing 6.5 g of potassium hydroxide (ACS reagent grade) with 100 ml of absolute 1-butanol (ACS reagent grade) and heat to dissolve the KOH. After the solution cools, filter the mixture through the glass-fiber filter paper.

40.2 Diphenylamine (1 percent solution). Prepare by dissolving 0.250 g of diphenylamine (ACS indicator grade) in 25 ml of sulfuric acid (sp gr 1.834).

40.3 Toluene (ACS reagent grade).

NOTE: Toluene is flammable and toxic. Avoid breathing vapors or contact with skin.

## 50. PROCEDURE

50.1 Pipette 10 ml of the sample into the reaction bottle and add 5 ml of toluene followed by 10 ml of the saponification mixture.

NOTE: Oral pipetting techniques should not be used because of the toxicity of the substances involved. A pipetting bulb or assembly similar to one of those described in 30.3 should be used.

50.2 Affix cap to the reaction bottle tightly and, after mixing the contents, place it in an oven maintained at 110° C for four hours.

50.3 Remove the reaction bottle from the oven and allow it to cool to 25° C plus or minus 3° C.

50.4 Filter the contents of the reaction bottle through the 60-ml glass-fritted crucible fitted with the glass fiber filter disc.

50.5 Wash the reaction bottle with 25 ml of toluene and transfer it to the glass-fritted crucible.

50.6 Carefully remove the glass fiber filter disc and dry it in oven at 110° C for 15 minutes.

50.7 Remove the filter disc and cool it to 25° plus or minus 3° C.

50.8 Add three drops of diphenylamine solution to the center of the disc and observe whether a blue or blue-black color forms.

## 60. REPORT

60.1 The presence of organic nitrate ester-type cetane improvers will be reported if the formation of a blue color occurs. Reference samples of diesel fuels containing 0.5 percent by volume of any one of the approved cetane improvers (see 3.2.3) give an intense blue to blue-black color throughout the



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APPENDIX

reagent spot whereas those samples containing only 0.1 percent by volume produce a blue ring at the outer boundary of the reagent. If a positive reaction occurs (i.e., a blue or blue-black coloration), the carbon residue determination (D 524) must be performed on a neat or basefuel blend.

APPENDIX C

Climatic/Geologic Variables Affecting Smoke Dispersion



## APPENDIX C

### Climatic/Geologic Variables Affecting Smoke Dispersion

#### 1. WINDS

Prevailing (steering) winds have the greatest influence on smoke operation. The prevailing winds blow between 9 and 800 meters above the ground surface. Smoke when produced moves to the level of the prevailing winds. Prevailing wind data are measured at an elevation of 16 meters.

The prevailing wind speed is the determining factor on how far the smoke producing equipment should be placed from the vital area to be screened. Wind speeds ranging from 5 to 15 km/h are ideal for the production of smoke screens. Wind speeds in excess of 15 km/h carry the smoke rapidly from its source. Therefore, more smoke producing equipment and/or material are required to produce the desired results. However, smoke produced by mechanical smoke generators may be effective in winds up to 17 km/h because of the great volume produced.

Wind direction is defined as the direction from which the wind blows. The direction of the wind determines the location of the smoke line to cover the vital area. Wind direction is classified as head wind, tail wind, flank and quartering winds. Head winds blow away from the smoke objective or vital area and directly to the smoke producing source. Tail winds are opposite of head winds. Flank winds blow across the smoke objective and smoke source. Quartering winds blow between the other winds. Requirements for smoke pots and fog oil are greater with quartering winds. Another system for surface wind designates wind direction by cardinal and intermediate points of the compass (north, northeast, east, southeast, south, southwest, west, and northwest).

#### 2. TEMPERATURE

The effect of temperature on smoke is slight. The only possible effect being the relationship of temperature to vapor pressure, relative humidity, and a warming of the smoke cloud due to solar radiation.

There are three types of temperature gradients that affect smoke screens: inversion, neutral, and lapse. Figure C-1 illustrates an artist's concept of the affect of the three types of temperature gradients on smoke clouds. Figure C-2 and C-3 show smoke disseminated from an M3A3 smoke generator during a lapse condition. An estimate of temperature gradient conditions is used to predict the stability of the air. Temperature gradients are measured by subtracting the air temperature 0.5 meter above the ground surface from the air temperature 4.0 meters above the surface. Submitted as figure C-4 is a graphic illustration of the measurement and classification of vertical temperature gradients.

A stable or inversion condition exists when the air temperature increases with an increase in altitude. This condition creates stable air currents and makes smoke linger for long periods. Under stable conditions, smoke streamers tend to travel parallel downwind for long distances before they spread and merge into a continuous blanket of smoke. Even after merging, this blanket of smoke lies low to the rising high enough to cover the tops of buildings or other tall objects.



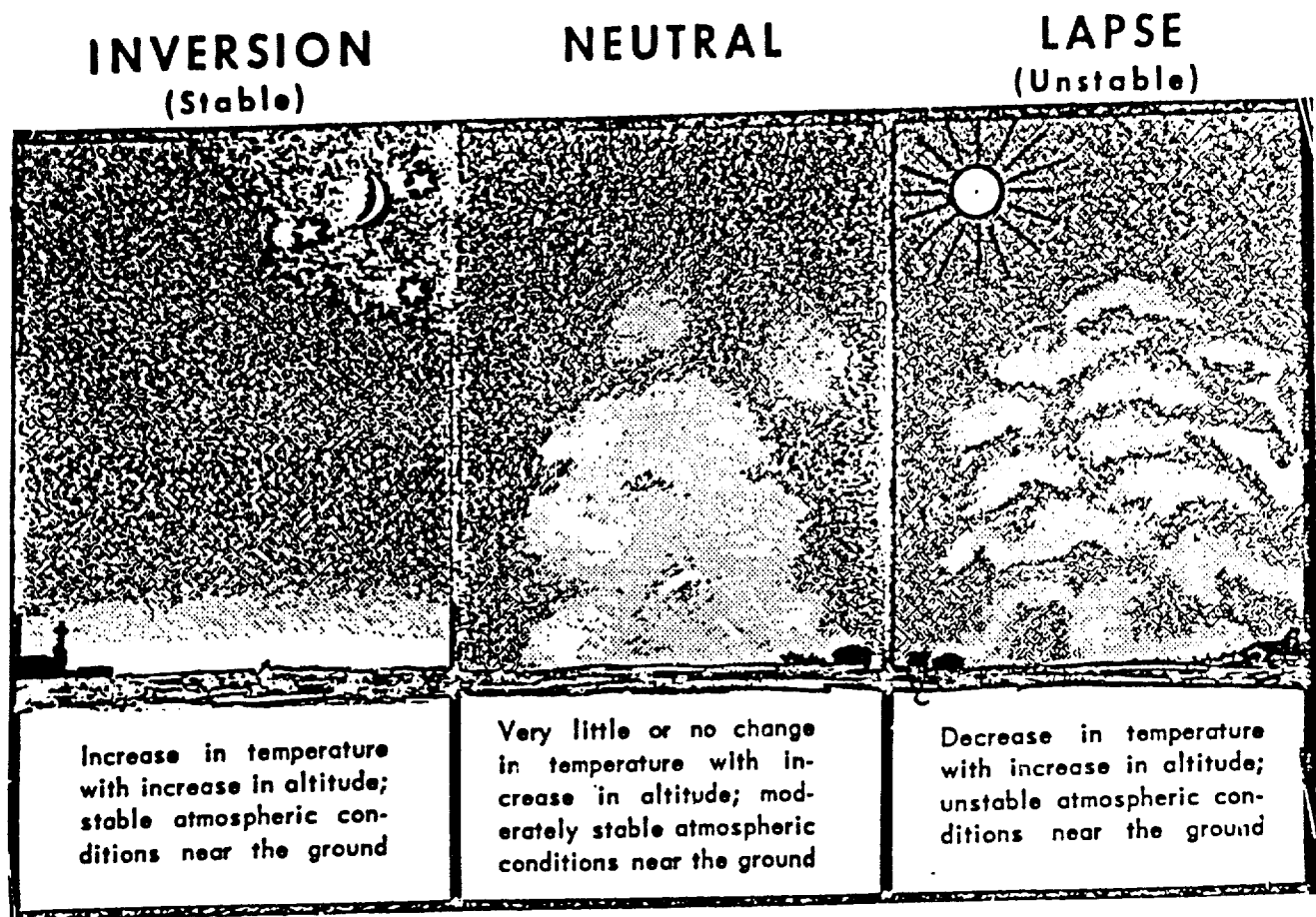


Figure C-1. Vertical temperature gradients.



Figure C-2. Oil smoke cloud rising during a tense condition.



Figure C-3. Oil smoke cloud rising during a lapse condition.

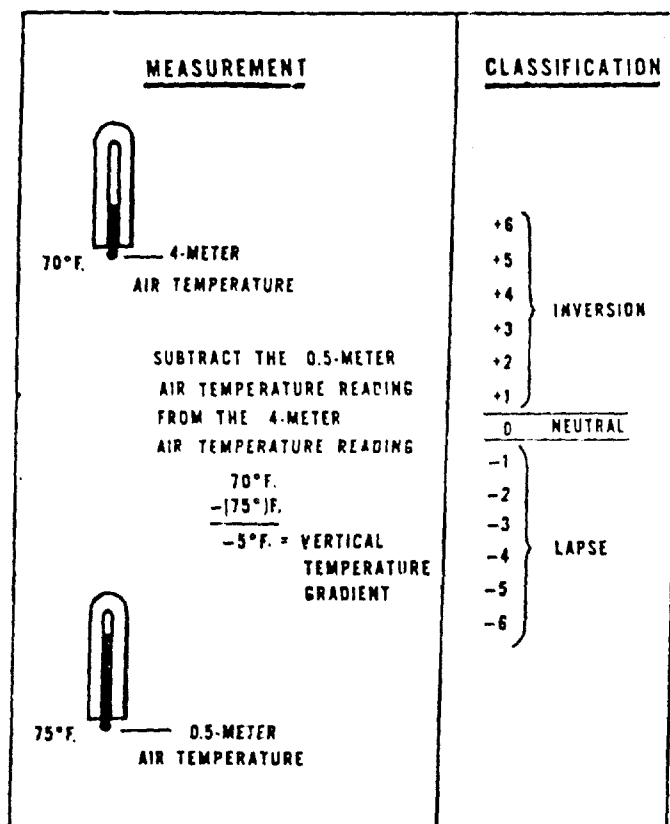


Figure C-4. Measurement and classification of vertical temperature gradients.

When there is little change in temperature based on altitude, conditions are neutral. Under neutral conditions, smoke streamers have steadier direction and there is less tendency for them to rise than when they are under unstable conditions. Also, streamers tend to spread and rise more quickly than under stable conditions. Therefore, neutral temperature gradients are best for smoke.

Unstable or lapse conditions are just the opposite of inversion; air temperature decreases as altitude increases. Unstable conditions cause smoke to break up because the air is moving. In low winds the smoke streamer may rise abruptly from the source. In higher winds the streamer may pass only a short distance downwind before rising and becoming diffused.

### 3. HUMIDITY

Petroleum distillates and PEG 200 as vaporized smoke clouds do not absorb moisture. The particle size is so minute that they tend to remain suspended in air until eventual evaporation which reduces the possible deposition rates.

### 4. PRECIPITATION

Light rains decrease visibility; therefore, less smoke is needed for concealment. Heavy rains and snow reduce visibility so that smoke is rarely necessary to provide concealment.

### 5. CLOUD COVER

When the sky is more than 70 percent covered with clouds, neutral temperature gradient conditions prevail. The atmosphere is moderately stable, and conditions are generally favorable for smoke.

### 6. TERRAIN

Since smoke is carried by the wind, it normally follows the earth's contours. On flat or unbroken terrain and over water, smoke streamers take longer to spread out and mix. On the other hand, trees and buildings tend to mix smoke streamers and increase smoke coverage. Large hill masses and rugged terrain cause strong crosscurrents which disperse smoke, causing holes and unevenness.

#### Arctic.

Smoke operations in arctic regions or other cold weather areas present special problems common to all types of units. Preventive maintenance for individual equipment in cold climates is given in appropriate technical manuals. Smoke generators can produce effective smoke clouds under arctic conditions when proper lubricants and fuel mixtures are used. On clear days, stable conditions exist over snowy surfaces. This condition is strongest about sunrise. Smoke tends to remain near the surface and may travel for long distances before dissipating. Under extremely cold conditions, smoke clouds last longer than under more temperate conditions. Snow or fog reduces visibility so that much less smoke is required for effective screening.



### Desert.

All deserts have certain characteristics in common--lack of surface water, sparse vegetation, extreme temperature ranges, and brilliant sunlight. Because of meteorological conditions and the vast areas usually available for dispersing and maneuvering troops, it is difficult to make beneficial use of smoke units. However, smoke can be used effectively for screening and deception. Smoke may be employed to screen an installation, to breach barriers and minefields, or to cover artillery positions at night to reduce muzzle flash. Desert sands absorb heat from the sun and cause appreciable horizontal temperature differences which in turn may cause whirlwinds. The soil is heated during the day to such an extent that smoke operations become extremely difficult because of strong unstable conditions. Smoke tends to pillar because of rising air currents. High winds and dust storms occur throughout the year. Smoke is more effectively in early morning and late evening or on an overcast day when neutral atmospheric conditions exist.

### Mountain.

Mountain operations are characterized by the difficulties encountered due to terrain. Generally, inadequate road nets found in mountain areas enhance the military value of existing roads and add importance to high ground that dominates other terrain. Smoke generators can screen artillery positions, supply routes, and preparations for installations and entrenchments. It can also reduce the enemy's ability to use high ground for observation. Small smoke units are often required to operate for extended periods with limited resupply in mountain operations because of transportation difficulties. Steep hills split winds so they eddy around and over the hill. Thermally induced slope winds occur throughout the day and night. These conditions make it extremely difficult to establish and maintain a smoke screen. Wind current, eddies, and turbulence must be continuously studied and observed.

### Jungle.

The jungle ordinarily affords concealment from air and ground observation. But, smoke screens may be employed in jungle operations to screen aircraft landing areas, to help prevent direct fire on helicopters approaching landing zones, and to screen landing zones while troops debark helicopters in the landing zone.

In many instances smoke use may be limited to coastal regions to conceal landings. In other areas, smoke may be used to conceal river crossings or to provide coverage of rivers used as routes of communication. Smoke used in dense vegetation tends to spread slowly downwind and downslope and follow creek beds and gullies. Jungle weather is usually hot, humid, and characterized by sudden changes. Within only a few minutes, clear, hot weather may change to torrential downpour. Windspeed in jungle areas normally does not exceed 3 kilometers per hour.

APPENDIX D  
Dissemination Models



## APPENDIX D Dissemination Models

The purpose of the following models is to provide estimates of downwind dosage and concentration levels resulting from the emission of smoke liquids (fog oil, diesel fuel and PEG 200), from the XM16 and XM52 smoke generators and to provide input to an environmental assessment required for disseminating smokes. Worst-case conditions were used: an inversion with wind speed less than 5 mph.

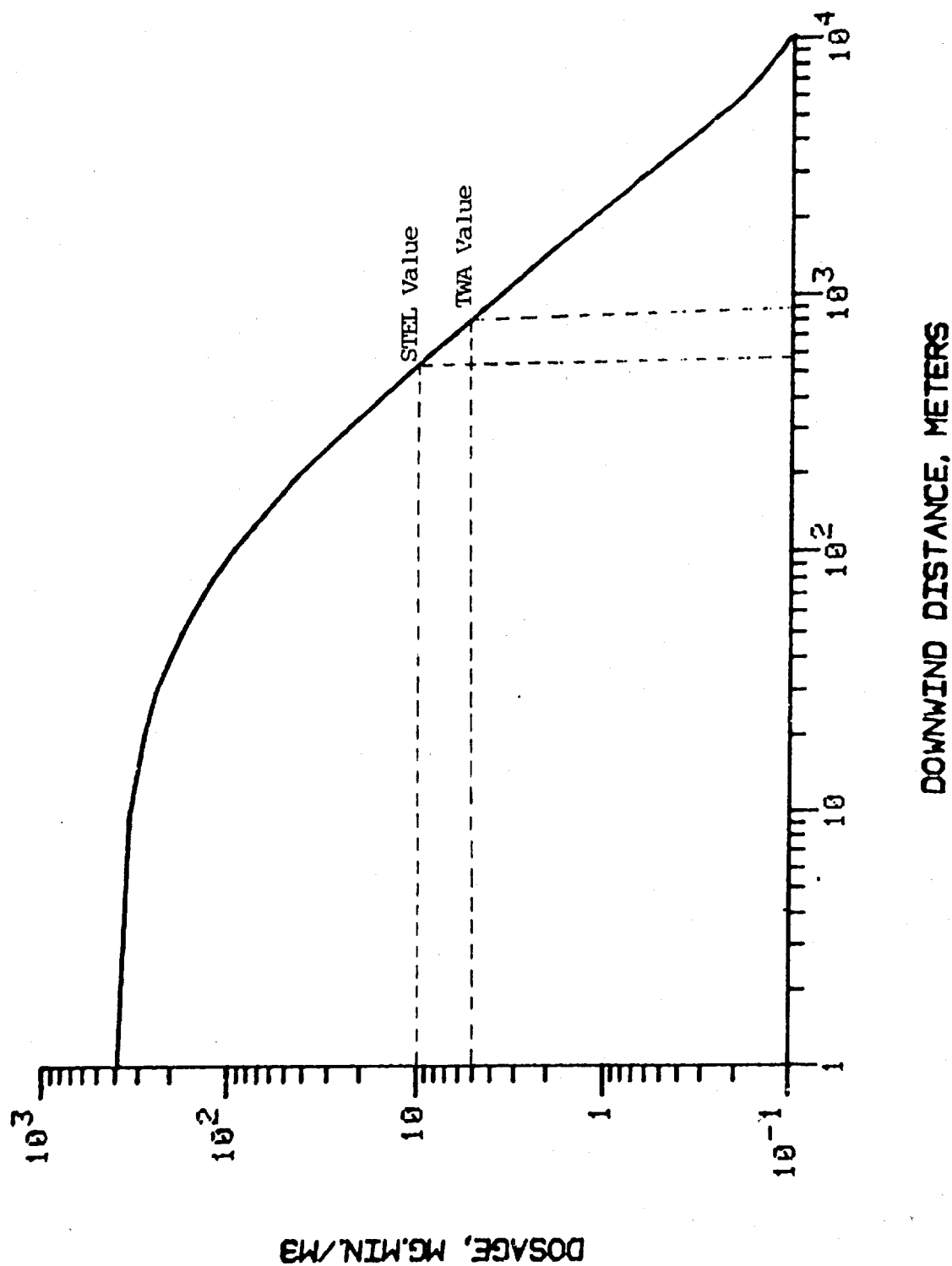
In May 1982 AMAF Industries, Inc. of Columbia, Maryland completed a computer program for smoke/obscurant hazard prediction entitled HAZRD2. This model was prepared for US Army Armament Research and Development Command. The following models were derived from the HAZRD2 program.

The simulation of the source cloud involves the estimation of the size of the cloud at the time the atmospheric forces take control of the mass emitted. The source sigmas in the Y- and Z-directions are estimated to be 1 m and the release height is about 2 m above the ground.

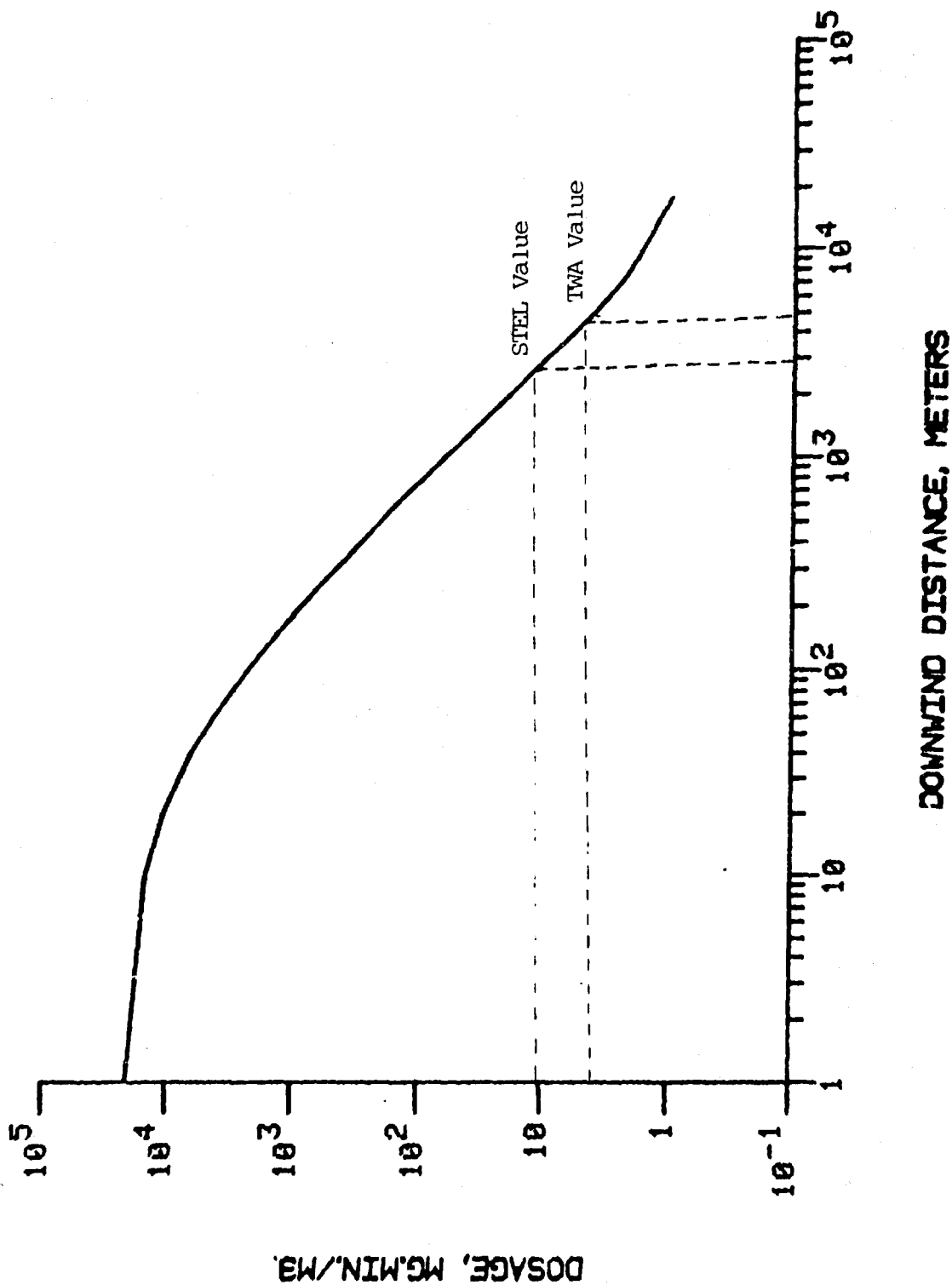
The results of the simulation are shown in the following graphs of concentration for 1 minute of emission. The results shown are for fog oil. While diesel fuel behaves differently as a screening agent, only the specific gravity differences would affect the predicted concentration and dosage patterns. Since diesel fuel is slightly less dense than fog oil, the fog oil estimates can serve as representative worst cases for this analysis.



# XM52 DOWNWIND DISTANCE VS DOSAGE, 1' OPERATION, 1GPM



XM16 DOWNWIND DOSAGE VS. DISTANCE, 1 MIN. OPERATION, 16 GPM



## APPENDIX E

### Toxicity of Fuel Oils and Lubricating Oils in Mammals



**APPENDIX E**  
**Toxicity of Fuel Oils and Lubricating Oils in Mammals**

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	Rats	Inhalation	7 hrs	14,400 mg/m <sup>3</sup>	acute LC <sub>50</sub>	Nau et al., 1966 (8)
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	Rats	Inhalation	18 hrs/day up to 2,424 hours of exposure	3200-3200 mg/m <sup>3</sup>	decreased rate of weight gain; neutrophilia; lymphocytopenia; decreased total leukocyte count; bilateral cataracts; hemorrhagic lungs, liver, kidneys, spleen; increased myelocytic precursors in bone marrow	Nau et al., 1966 (8)
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	Rats	Inhalation	18 hrs/day; 5 days/wk 700 hr total	260-1000 mg/m <sup>3</sup>	no adverse effects	Nau et al., 1966 (8)
Vapors of C <sub>11</sub> -C <sub>12</sub> aromatic distillate	Rats	Inhalation	7 hrs	4600 mg/m <sup>3</sup>	acute LC <sub>50</sub>	Nau et al., 1966 (8)
Vapors of C <sub>11</sub> -C <sub>12</sub> aromatic distillate	37 Rats	Inhalation	18 hrs/day up to 1683 hours of exposure	3200 mg/m <sup>3</sup>	50% died after 18 hr; decreased rate of weight gain; hemorrhagic lungs; liver; splenic dystrophy; decreased total leukocyte count; neutrophilia; lymphocytopenia; watery bone marrow; dermatitis.	Nau et al., 1966 (8)



Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	CFW mice	Inhalation	3.75 hours	9700 mg/m <sup>3</sup>	acute LC <sub>50</sub>	Nau et al., 1966 (8)
Vapors of C <sub>11</sub> -C <sub>12</sub> aromatic distillate	CFW mice	Inhalation	3.75 hours	3400 mg/m <sup>3</sup>	acute LC <sub>50</sub>	Nau et al., 1966 (8)
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	3 rhesus monkeys	Inhalation	7 hr/day; 5 days/wk 90 exposures	1000 mg/m <sup>3</sup>	hair loss; dry skin; sedation; tremor leukocytopenia; neutrophilia; lymphocytopenia, decreased erythrocytic and myelocytic precursors in bone marrow	Nau et al., 1966 (8)
Vapors of C <sub>9</sub> -C <sub>10</sub> aromatic distillate	3 rhesus monkeys	Inhalation	7 hr/day; 4 days/wk 90 exposures	260 mg/m <sup>3</sup>	elevated hematocrit; leukocytopenia; neutrophilia; lymphocytopenia	Nau et al., 1966 (8)
Vapors of C <sub>11</sub> -C <sub>12</sub> aromatic distillate	4 rhesus monkeys	Inhalation	7 hr/day; 5 days/wk 90 exposures	300 or 1280 mg/m <sup>3</sup>	eye and skin irritation; diarrhea; neutrophilia and lymphocytopenia, increased erythrocytic and decreased myelocytic precursors in bone marrow	Nau et al., 1966 (8)
diesel fuel	Wistar rats	Intratracheal		0.01-0.10 ml/animal	pulmonary surfactant layer damage	Keen, 1968 (23)
diesel fuel	Wistar rats	Intratracheal	during apneic state	0.02 ml/animal	both rats died in 24 hr of acute aspiration pneumonitis and pulmonary edema	Gerarde, 1963 (24)



Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
diesel fuel or kerosene	Wistar rats	Intratracheal		0.10 ml/kg (0.025 ml/animal)	pneumonia; resolution in 14 days	Keen, 1968 (23)
diesel fuel	Wistar rats	Intratracheal		0.05 ml/animal	acute LD <sub>50</sub>	Keen, 1968 (23)
diesel fuel	rabbits	Intratracheal		1.0 ml/animal	progressive interstitial pneumonitis; alveolar hemorrhage; bronchiolar necrosis after 6-8 days	Haraszti and Sovari, 1968 (25)
undiluted diesel fuel	Wistar rats	Tail skin	6 hr/day for 10 days		dermatitis; hair loss; decreased hemoglobin; erythrocytopenia; reticulocytosis; leukocytosis; neutrophilia; lymphocytopenia	Starek et al., 1976 (26)
diesel fuel	5 albino guinea pigs	intracapular skin	5 times/wk for 19 days		erythema; desquamation; hair loss; ulceration and crusting	Bien and Bunrock 1969 (27)
diesel fuel	24 guinea pigs	Landesteiner & Jacobs skin sensitization method			no skin sensitization	Starek et al., 1976 (26)
diesel fuel	10 white Belgian rabbits	Draize method			mild primary irritant to skin and conjunctiva	Starek et al., 1976 (26)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
C <sub>9</sub> -C <sub>12</sub> aromatic distillate	79 C <sub>3</sub> H mice	Dermal	3 times/wk; 150 applications total	0.10-0.15 g/animal	dry, thick scaly skin; hyperkeratosis; epidermal atrophy; dermatitis; ulceration	Nau et al., 1966 (8)
Light grade diesel fuel	100 mice	intrascapular skin	daily application		dermatitis	Twort and Twort, 1935 (28)
Heavy grade diesel fuels	100 mice	intrascapular skin	daily application		18 tumors; 3/18 became malignant	Twort and Twort, 1935 (28)
SGF No. 1	250 one month old strain A mice	Inhalation	30 min of aerosol and 30 min of room air for 343 days	63 mg/m <sup>3</sup>	excess of pulmonary tumors; oil deposition in mediastinal and peribronchial lymph nodes; no excess pneumonia	Lushbaugh et al., 1950 (29)
SGF No. 1	4 rabbits	Inhalation	same as above for one year	63 mg/m <sup>3</sup>	no pulmonary tumors; oil deposition in pulmonary lymphatics	Lushbaugh et al., 1950 (29)
SGF No. 1	80 albino rats	Inhalation	same as above for one year	63 mg/m <sup>3</sup>	no pulmonary tumors; no excess pneumonia; minimal oil accumulation in lungs	Lushbaugh et al., 1950 (29)
SGF No. 1	7 rhesus monkeys	Inhalation	30 min of aerosol and 30 min of room air for 343 days	63 mg/m <sup>3</sup>	5 deaths-after 44, 67, 71, 77 and 97 days of exposure; progressive thinning of fur and baldness; progressive pulmonary oil accumulation and focal pneumonia; excess infectious pneumonia; gastric ulcerations and atrophy; 2 gastric adenocarcinomas	Lushbaugh et al., 1950 (29) and Lushbaugh et al., 1945 (9)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
diesel oil	Wistar rats	gastric intubation	14 days	20-25 ml/kg of body weight	hemoglobinemia; reticulocytosis; neutrophilia; lymphocytopenia; thrombocytopenia; elevated serum malate dehydrogenase, aspartate and alanine aminotransferase	Starek et al., 1975 (7)
diesel oil	138 Wistar rats	gastric intubation		16.0 ml/kg of body weight	acute oral LD <sub>50</sub>	Starek et al., 1975 (7)
diesel oil	5 Wistar rats	gastric intubation	daily for approx. 3 weeks	6.9 ml/kg of body weight	subacute oral LD <sub>50</sub>	Starek et al., 1975 (7)
kerosene	9 Wistar rats	duodenal intillation	2.0-3.0 ml/animal		no changes in lung stability in 18-24 hour	Keen, 1968 (23)
fuel oil	10 rabbits	oral	1.0 ml/kg of body-weight		23% drop in blood sugar in 5-7 hr; return to normal levels by 12 hr.	Tani, 1939 (30)
diesel fuel	cow	accidental ingestion	approx. 7 liters		low grade fever; diarrhea; constipation; lowered milk production; stiff uncertain gait; swelling of hind fetlocks; recovery in 8 days	Messerli, 1969 (14)
diesel fuel soaked grass	ewe	ingestion			weakness; weight loss; diesel fuel odor on breath, urine and feces; slight pulmonary involvement; nodular lesions on inner rumen wall; complete loss of fleece; neutrophilia; normochromic anemia	Ranger, 1976 (15)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
aerosol of S.A.E. 10-20 motor oil	30 albino mice	Inhalation	4 hours	200 mg/m <sup>3</sup>	very mild hyperplasia tracheobronchial epithelium	Wagner et al., 1961 (31)
aerosol of S.A.E. 10 motor oil	6 albino mice	Inhalation	2 hours	4330 mg/m <sup>3</sup>	oil retention in terminal bronchioles and alveolar ducts; vigorous oil phagocytosis	Shoshkes et al., 1950 (32)
aerosol of S.A.E. 10 motor oil	7 albino mice	Inhalation	92 hr total intermittently	4330 mg/m <sup>3</sup>	one death; heavy oil retention in all divisions of respiratory tree; pneumonia; coalescence of oil into giant droplets ( $> 30 \mu$ diameter)	Shoshkes et al., 1950 (32)
aerosol of S.A.E. 10 motor oil	6 albino mice	Inhalation	2 hrs	4500 mg/m <sup>3</sup>	2 deaths; oil retention in terminal bronchioles and alveolar ducts; vigorous oil phagocytosis	Shoshkes et al., 1950 (32)
aerosol of S.A.E. 10 motor oil	13 albino mice	Inhalation	90 hrs total intermittently	4500 mg/m <sup>3</sup>	3 deaths; extremely heavy oil retention in all divisions of respiratory tree; pneumonia; coalescence of oil into giant droplets ( $> 30 \mu$ diameter)	Shoshkes et al., 1950 (32)
aerosol of mineral oil	20 Wistar rats	Inhalation	6 hr/day for 3 wks	30,000 mg/m <sup>3</sup>	increased macrophages and foam cells in alveolar lumina and septae; oil deposition in 2 weeks; decreased adenosine triphosphate activity of macrophages; focal oil granulomas and pneumonia in 3 weeks	Eckert and Kandt, 1975 (33)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
aerosol of S.A.E. 10 motor oil	6 rhesus monkeys	Inhalation	30 min aerosol alternated with 30 min room air for 100 days	132 mg/m <sup>3</sup>	2 deaths; oil accumulation in lungs followed by gradual clearing over one year; pneumonia; bronchiolitis; pulmonary fibrosis; pulmonary edema; weight loss; atrophic stomach; fur loss	Lushbaugh et al., 1945 (29) and Wager et al., 1964 (10)
aerosol of S.A.E. 10 motor oil	80 white mice	Inhalation	30 min aerosol alternated with 30 min room air for 100 days	132 mg/m <sup>3</sup>	gradual oil accumulation in lung macrophages in peripheral and sub-pleural alveoli; no free oil; oil macrophages in tracheobronchial lymph nodes; minimal toxicity	Lushbaugh and Cannon, 1942 (34)
aerosols of industrial lubricating oils	30 rats	Inhalation	5 hr/day for 6 months	13, 30, or 60 mg/m <sup>3</sup>	serum neuraminic acid levels increased progressively; decrease of serum albumin and leukocyte phagocytic activity; increased serum globulins	Lutov, 1973 (35)
aerosol of mineral oil	218 golden Syrian hamsters	Inhalation	5 days/wk; 6 hrs/day; 26 months	5 or 100 mg/m <sup>3</sup>	no major lung tissue response; presence of oil macrophages in alveoli; no other pathological findings	Wagner et al., 1964 (10)
aerosol of mineral oil	46 Dutch rabbits	Inhalation	5 days/wk; 6 hrs/day; 26 months	5 or 100 mg/m <sup>3</sup>	no adverse effects	Wagner et al., 1964 (10)
aerosol of mineral oil	18 mongrel dogs	Inhalation	5 days/wk; 6 hrs/day; 26 months	5 or 100 mg/m <sup>3</sup>	pulmonary tissue damage indicated by elevated lung alkaline phosphatases; scattering and coalescence of oil droplets in lungs; granulomas with intracellular oil droplets	Wagner et al., 1964 (10)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
S.A.E. 10-20-30 motor oil	5 albino Wistar rats	Intratracheal Aspiration		0.2 ml/animal	one death in 24 hr; low grade localized pneumonia; no epithelial irritation	Gerarde, 1963 (24)
White mineral oil	mice	oral ingestion	daily	20 ml/kg of body weight	rough, dry skin; piloerection; restlessness; weight loss in 5 days; all died by 7-10 days; fatty degeneration of liver; proliferation of reticuloendothelial cells of spleen; epidermal hyperkeratosis; renal tubular degeneration	Brahmachari, 1958 (36)
White mineral oil	rats	oral ingestion	daily	5 ml/kg of body weight	same as above in mice	Brahmachari, 1958 (36)
White lubricating oil	2 Holstein-Friesian calves	dermal application	daily for 8 weeks	0.13 ml/kg of body weight	no gross skin pathology	Hoekstra et al., 1955 (38)
White lubricating oil	albino guinea pigs	dermal application	every other day for 4 days	0.6 ml/animal	slight erythema and desquamation	Hoekstra and Phillips, 1963 (38)
Yellow lubricating oil	albino guinea pigs	dermal application	every other day for 4 days	0.6 ml/animal	desquamation and hyperkeratosis	Hoekstra and Phillips, 1963 (38)
aerosol mineral oil	250 CAF/JAX mice	Inhalation	6 hr/day; 5 days/wk for 16 months	100 mg/m <sup>3</sup>	equivocal evidence of altered rate of lung tumor formation in this tumor-susceptible species	Wagner et al., 1964 (10)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
DF-2 smoke & exhaust from the VESS	Sprague- Dawley Rats	Inhalation	15-300 min & ob- served for 14 days	35,230 + 7210 mg/m <sup>3</sup> @ 15+60 min, 15,930 + 5840 mg/m <sup>3</sup> @ 120+300 min	No mortalities at 15-20 min. 30% mortality occurred at 180 min. Toxic signs exhibited were lethargy, cyanosis, hypopnea, and piloerection	Callahan et al., 1982 (5)
DF-2 smoke/ exhaust from the VESS	Fischer 344 Rats	Inhalation	15-300 min and 14 days observation	same as above	No mortalities at 15 min. 10% mortality occurred at 60 min. Toxic signs exhibited were lethargy, cyanosis, hypopnea, piloerection, and prostration	Callahan et al., 1982 (5)
DF-2 smoke/ exhaust from the VESS	Hartley Guinea Pigs	Inhalation	15-300 min and 14 days observation	same as above	No mortalities at 15 min 40% mortality occurred at 60 min Toxic signs exhibited were lethargy, lacrimation, oral & nasal frothiness, nasal hemorrhage, tremors, cyanosis, apnea, hypopnea, and piloerection	Callahan et al., 1982 (5)
DF-2 smoke/ exhaust from the VESS	mice	Inhalation	15-300 min and 14 days observation	same as above	No mortalities at 15-180 min 60% mortality occurred at 300 min. Toxic signs exhibited were hypopnea, lethargy, piloerection, tremors, and prostration.	Callahan et al., 1982 (5)
DF-1 smoke/ exhaust from the VESS	Sprague- Dawley Rats	Inhalation	15-300 min and ob- served for 14 days	14,240 + 5790 mg/m <sup>3</sup>	No mortalities at 15 and 60 min 20% mortality occurred at 180 min. Toxic signs exhibited were cyanosis, apnea, lethargy, lacrimation, nasal hemorrhage, exophthalmos, convul- sions, and prostration	Callahan et al., 1982 (5)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
DF-1 smoke/exhaust from the VEESS	Hartley Guinea Pigs	Inhalation	15-300 min & observed for 14 days	same as above	No mortalities at 15 and 60 min. 70% mortality occurred at 120 min. Toxic signs exhibited were apnea, lethargy, lacrimation, nasal hemorrhage, tremors, convulsions, and prostration	Callahan et al., 1982 (5)
Referee-Grade I (arctic) diesel fuel smoke/exhaust	Spague-Dawley Rats	Inhalation	15-180 min and 14 days observation	16,220 ± 6580 mg/m <sup>3</sup>	No mortalities at 15 and 60 min. 40% mortality occurred at 180 min. Toxic signs exhibited were hypopnea, lethargy, lacrimation, nasal frothiness and hemorrhage, blood in eyes, tremors, convulsions, and prostration	Callahan et al., 1982 (5)
Referee-Grade I (arctic) diesel fuel smoke/exhaust	Hartley Guinea Pigs	Inhalation	15-180 min and 14 days observation	same as above	No mortalities at 15 and 60 min. 90% mortality occurred at 180 min. Toxic signs exhibited were hypopnea, lethargy, lacrimation, nasal frothiness and hemorrhage, blood in eyes, tremors, convulsions, and prostration	Callahan et al., 1982 (5)
Referee-Grade II (Regular) diesel fuel smoke/exhaust	Sprague-Dawley Rats	Inhalation	15-180 min and 14 days observation	8,940 ± 3850 mg/m <sup>3</sup>	No mortalities at 15 and 60 min. 70% mortality occurred at 180 min. Toxic signs exhibited cyanosis, hypopnea, lethargy, blood in eyes, exophthalmos, convulsions, and prostration	Callahan et al., 1982 (5)



Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
Reicree-Grade II (Regular) diesel fuel smoke/exhaust	Hartley Guinea Pigs	Inhalation	15-180 min and 14 days observation	same as above	No mortalities at 15 min. 40% mortality occurred at 60 min. Toxic signs exhibited were cyanosis, hypopnea, lethargy, lacrimation, nasal hemorrhage, tremors, convulsions and prostrations	Callahan et al., 1982 (6)
Diesel Fuel	Sprague-Dawley Rats	Inhalation	10 min	3,750 mg/m <sup>3</sup>	RD <sub>50</sub> (50% depression of respiratory frequency)	Dalbey, 1982 (39)*
DF-2 smoke/exhaust from the VEES	Rats	Inhalation	15-60 min	2,340 ± 450 mg/m <sup>3</sup>	Teratologic investigations evidenced fatal malformations (i.e. exencephaly, reduction in weight, clubbed feet, spina bifida, distorted cranium, skeletal malformation, hemorrhage of the olfactory bulbs, and intestines extruding at the umbilicus site.)	Starke et al., 1982 (40)
PEG 200	Cyno-molgus monkeys	oral	daily for a 13-week period	2-4 ml/kg	Pathological lesions consisting of intratubular deposition of small numbers of oxalate crystals in the renal cortex.	Prentice et al., 1978 (11)
PEG 200	Sprague-Dawley Rats	oral	daily for a 13-week period	2.5-5.0 ml/kg	no adverse affects	Prentice et al., 1978 (11)

\*Results of early investigations of toxicologic effects of diesel fuel smokes performed by Oak Ridge National Laboratory and documented in one of their monthly reports.

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
PEG 200	mice	intraperitoneal	one dose	4.6 ml/kg	LD <sub>50</sub> , ED <sub>0</sub> (highest dose at which no effects are seen in the test population) was achieved at 1.0 ml/kg	Worthley et al., 1966 (41)
PEG 200	Rats	Inhalation	6 hrs	2516 mg/m <sup>3</sup>	no toxic signs evident; LCt <sub>50</sub> was greater than 905,670 mg min/m <sup>3</sup>	Crook et al., 1981 (12)
PEG 200	Mice	Inhalation	6 hrs	2516 mg/m <sup>3</sup>	no toxic signs evident; LCt <sub>50</sub> was greater than 905,670 mg min/m <sup>3</sup>	Crook et al., 1981 (12)
PEG 200	Rats	Intravenous		5.0-10.0 ml/kg	No toxic signs or death at the 5.0 ml/kg dosage; Ataxia in all rats and one death at the 10.0 ml/kg dosage. Acute LD <sub>50</sub> for PEG 200 greater than 10.0 ml/kg	Crook et al., 1981 (12)
PEG 200	Rats	oral		17.8 - 36.0 gm/kg	100% ataxia and mortality. LD <sub>50</sub> found to be 28.13 gm/kg. Toxic signs included convulsions and prostration	Crook et al., 1981 (12)
PEG 200	Fruit Flies	oral		0.01%-50% in distilled water	Acute LD <sub>100</sub> at the 10% concentration. A single mutation at the lowest concentration of 0.01%, but was statistically insignificant at the 0.05 or 0.01 level.	Crook et al., 1981 (12)
PEG 200	Mice	Intraperitoneal		1.0-10.0 ml/kg	LD <sub>100</sub> at 10.0 ml/kg; LD <sub>50</sub> at 7.5 ml/kg; ED <sub>0</sub> at 1.0 ml/kg	Christensen et al., 1979 (42)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
PEG 200	6 Rabbits	Percuta- neous	daily/5 days/wk for 18 weeks	2 ml/kg/day	No fatalities. Body weight, blood urea and icteric index of treated animals did not differ from controls Primary irritation not evident.	Christensen et al., 1979 (42)
PEG 200	Mice	Intravenous	one dose	6.3-12.5 ml/kg	24 hr LD <sub>50</sub> was 8.84 ml/kg 14 day LD <sub>50</sub> was 8.45 ml/kg	Manthei, et al., 1980 (43)
DF-A	Mice	Intravenous	one dose	0.5-1.26 ml/kg	24 hr LD <sub>50</sub> was 0.72 ml/kg 14 day LD <sub>50</sub> was 0.72 ml/kg	Manthei, et al., 1980 (43)
DF-1	Mice	Intravenous	one dose	0.5-1.0 ml/kg	24 hr LD <sub>50</sub> was 0.71 ml/kg 14 day LD <sub>50</sub> was 0.69 ml/kg	Manthei, et al., 1980 (43)
DF-2	Mice	Intravenous	one dose	0.5-1.0 ml/kg	24 hr LD <sub>50</sub> was 0.92 ml/kg 14 day LD <sub>50</sub> was 0.87 ml/kg	Manthei, et al., 1980 (43)
DF-Referee Grade - 2	Mice	Intravenous	one dose	0.5-1.0 ml/kg	24 hr LD <sub>50</sub> was 0.75 ml/kg 14 day LD <sub>50</sub> was 0.72 ml/kg	Manthei, et al., 1980 (43)
Diesel fuels	Rabbits	Percutaneous	one dose	2.0 ml/kg	No toxic signs. Moderate to severe skin irritation at 24 hrs. At 14 days skin became scabbed and dry to scaley with moderate erythema.	Manthei, et al., 1980 (43)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
Diesel fuels DF-1, DF-2, DF- A, and Referee Grade	Rats	oral	one dose	5.0 ml/kg	no mortality after 14 days	Manthei, et al., 1980 (43)
DF, Referee Arctic, DF1, DF2, DF Referee Regular	Rabbit	Ocular	single dose	0.1 ml	No eye irritation observed through- out 7-day observation period.	Manthei, et al., 1980 (43)
DF Referee, Arctic, DF1 DF2, DF Referee Regular	Rabbit	Dermal: Intact & Abraded	single dose	0.5 ml	Primary skin irritant; erythema, edema and eschar formation through- out the 72 hour observation period.	Manthei, et al., 1980 (43)
PEG 200	Rabbits	Percuta- neous	one dose	2.0 ml/kg	No toxic signs. No skin irritation	Manthei, et al., 1980 (43)
DF-A	Rats	Inhalation	1 hour	21 mg/l	No toxic signs. No mortalities	Manthei, et al., 1980 (43)
DF-1	Rats	Inhalation	1 hour	22 mg/l	Eye irritation and redness of extre- mities for 1 hour after exposure. No mortalities.	Manthei, et al., 1980 (43)
DF-2	Rats	Inhalation	1 hour	25 mg/l	Eye irritation and redness of extre- mities for 1 hour after exposure. No mortalities.	Manthei, et al., 1980 (43)

Petroleum Distillate Type	Species	Exposure Route	Exposure Time	Conc.	Results	Reference
DF-Referee Grade	Rats	Inhalation	1 hour	22 mg/l	No toxic signs. No mortalities	Manthei et al., 1980 (43)
PEG-200	Rats	Inhalation	1 hour	23.1 mg/l	No toxic signs. No mortalities	Manthei et al., 1980 (43)
PEG 200	Fischer 344 rats	Inhalation	6 hrs/day/5 days/wk for 13 weeks	100 mg/m <sup>3</sup>	No toxic signs nor deaths were evident after the 13 week exposure period.	Crook et al., 1981 (44)
PEG 200	Fischer 344 rats	Inhalation	same as above	1000 mg/m <sup>3</sup>	No toxic signs nor deaths were evident after the 13 week exposure period.	Crook et al., 1981 (44)
PEG 200	Mice	Inhalation	same as above	100 mg/m <sup>3</sup>	No toxic signs nor deaths were evident after the 13-week exposure period	Crook et al., 1981 (44)
PEG 200	Mice	Inhalation	same as above	1000 mg/m <sup>3</sup>	No toxic signs nor deaths were evident after the 13-week exposure period.	Crook et al., 1981 (44)

## **APPENDIX F**

### **Summary of Toxicity of Fuel Oils and Lubricating Oils in Algae, Phytoplankton, and Bacteria**



APPENDIX F  
Summary of Toxicity of Fuel Oils and Lubricating Oils in  
Algae, Phytoplankton, and Bacteria

TOXICITY OF FUEL OILS AND LUBRICATING OILS IN ALGAE,  
PHYTOPLANKTON, AND BACTERIA\*

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Natural marine phytoplankton communities	Exposure to 19.1 to 19.8 $\mu$ g/l No. 2 fuel oil dissolved in water	Inhibition of photo- synthesis	Gordon and Prouse, 1973
Fresh water Phytoplankton (Algae): Euglena	Cultured and grown on 0.1% diesel fuel medium or on 10% lubricating oil medium	No reduction in popu- lation size or growth rate	Dennington et al., 1975
Scenedesmus	Cultured and grown on 0.1% diesel fuel medium	No growth; inhibition of photosynthesis	"
"	Cultured and grown on 0.1% lubricating oil medium	Inhibition of photosynthesis	"
Skeletonema (diatom)	Stoppered flask culture with 100 $\mu$ g/l of No. 2 fuel oil medium	No growth	Dunstan et al., 1975
"	Unstoppered flask culture with 1000 $\mu$ g/l of No. 2 fuel oil medium	No growth	"
Dunaliella (green flagel- late)	Flask culture with $\mu$ g/l quantities of No. 2 fuel oil medium	Enhanced growth	"
"	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	No effect on growth	Pulich et al., 1974
Chlorella (green)	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	No effect on growth	"

\*References are taken from Liss-Suter, Deborah. A Literature Review-Problem Definition Studies on  
Selected Toxic Chemicals, Volume 8 of 8.

SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS  
IN ALGAE, PHYTOPLANKTON, AND BACTERIA (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES
Agmenellum (blue-green)	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	7-hr lag phase	"
Thalassiosira (diatom)	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	14-hr lag phase	"
Gymnodinium (dinoflagellate)	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	170-hr lag phase	"
Nostoc (blue-green)	Cultured on 10% dilution of seawater with 15 mg/l No. 2 fuel oil	Prolongation of doubling time from 6 to 9 hours	Pulich et al., 1974
Agmenellum (blue-green)	Suspension in 50% dilution of soluble fraction of 10.1% No. 2 fuel oil in water mixture	Inhibited photo- synthesis	"
Chlorella (green)	Suspension in 20% dilution of soluble fraction of 10.1% No. 2 fuel oil in water mixture	Inhibited photo- synthesis	"
Thalassiosira (diatom)	Suspension in 12% dilution of soluble fraction of 10.1% No. 2 fuel oil in water mixture	Inhibited photo- synthesis	"
Coccochloris (blue-green)	In 25% dilution of soluble fraction of 10.1% Baytown or Montana fuel oils mixed with water	No growth	Winters et al., 1976
Agmenellum (blue-green)	In 25% dilution of soluble fraction of 10.1% Baytown or Montana fuel oils mixed with water	No growth	"



SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS  
IN ALGAE, PHYTOPLANKTON, BACTERIA (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES
Dunaliella (green)	Suspension in 50% dilution of soluble fraction of 10.1% New Jersey fuel oil mixed with water	No growth	"
Chlorella (green)	Suspension in 50% dilution of soluble fraction of 10.1% New Jersey fuel oil mixed with water	No growth	"
Mixed culture of motile marine bacteria	Kerosene emulsion ≥5 µg/l in seawater	Motility adversely affected	Chet and Mitchell 1976
"	Kerosene emulsion 3 µg/l in seawater	Blockage of chemical- ly - mediated attrac- tion to organic matter in water	"

## APPENDIX G

### Summary of Toxicity of Fuel Oils and Lubricating Oils in Waterfowl



## APPENDIX G

### SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS IN WATERFOWL

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Waterfowl	Field studies in fuel oil-polluted environments	Inability to fly; preening to the exclusion of feeding; loss of buoyancy and drowning; loss of insulation against cold.	Hunt and Ewing, 1953
Waterfowl	Field studies in diesel-fuel polluted area	Oil swallowing caused burns, pneumonia, internal hemorrhages, comatose behavior	Chia, 1971
1-year-old Mallard ducks	Intragastric administration of gelatin capsules containing >20 mg/kg b.w. of diesel fuel	LD <sub>50</sub> ; weakness, diarrhea, regurgitation.	Tucker and Crabtree, 1970
Pekin and Mallard ducks	Intragastric administration of 4 ml/kg b.w. of diesel fuel under stress conditions of crowding and 0 to -10°C.	LD <sub>50</sub>	Hartung and Hunt 1966
Ducks	Intragastric administration of 24 ml/kg b.w. of diesel fuel	No mortalities	"
Ducks	Intragastric administration of 20 ml/kg b.w. of lubricating oil	No mortalities	"

\*References are taken from Liss-Suter, Deborah. A Literature Review-Problem Definition Studies on Selected Toxic Chemicals, Volume 8 of 8.

LD<sub>50</sub> - median lethal dose

b.w. - body weight

Appendix G



SUMMARY OF TOXICITY OF FUEL OILS AND  
LUBRICATING OILS IN WATERFOWL (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Quail	Oral administration of capsules containing 3.5 mg/kg b.w. of No. 2 fuel oil	Egg production halted for 6-8 days; egg yolk deposition abnormalities	Grau, 1977
Mallard and Pekin ducks	Intragastric administration of 1-3 ml/kg b.w. of fuel oil or lubricating oil	Oil pneumonia, diarrhea, anemia, occult blood in intestines, toxic nephrosis	Hartung and Hunt 1966
Ducks	Intragastric administration of 3-12 ml/kg b.w. of diesel fuel	Liver function alterations, reduced pancreatic zymogen, toxic nephrosis, lipid pneumonia, diarrhea, occult blood in intestines, anemia	Hartung and Hunt 1966

## **APPENDIX H**

### **Summary of Toxicity of Fuel Oils and Lubricating Oils in Aquatic Life**

# APPENDIX H

## SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS IN FISH

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Bluegill sunfish	Exposure to 3000 mg/l kerosene added to water	24-hr LC <sub>50</sub>	Turnbull et al., 1954
Banded killifish	Exposure to 28.5 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	Rehwoldt et al., 1974
"	Exposure to 26.1 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
Striped bass	Exposure to 30.6 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to 22.2 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
Pumpkinseed	Exposure to 42.6 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to 39.2 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
White perch	Exposure to 41.6 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to 37.2 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
American eel	Exposure to 28.0 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to 31.0 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
Carp	Exposure to 52.5 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to 49.1 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"

\*References are taken from Liss-Suter, Deborah. A Literature Review-Problem Definition Studies on Selected Toxic Chemicals, Volume 8 of 8.

LC<sub>50</sub> - median lethal concentration

TL<sub>m</sub> - median tolerance limit

Appendix H

SUMMARY OF TOXICITY OF FUEL OILS AND  
LUBRICATING OILS IN FISH (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Juvenile American Shad "	Exposure to 204 mg/l diesel fuel added to water Exposure to 167 mg/l diesel fuel added to water	24-hr $TL_m$ ; loss of equilibrium, and other central nervous system disturbances preceded death	Tagatz, 1961
	Exposure to 200 mg/l kerosene added to water Exposure to 200 mg/l No. 2 fuel oil added to water	24-hr $TL_m$ 24-hr $TL_m$	Boylan and Tripp 1971 "
Mummichog	Exposure to undiluted soluble fraction of 10% mixture of No. 2 fuel oil in water	No mortalities in 96 hr	Scheier and Cominger, 1976
Sheephead Minnow	Exposure to same	No mortalities in 96 hr	"
Channel catfish	Exposure to same	10% mortality in 96 hr	"
Bluegill sunfish	Exposure to same	20% mortality in 96 hr	"
Mummichog	Exposure to 48 vol % dilu- tion of soluble fraction of 10% mixture of No. 2 fuel oil in water pre- viously UV irradiated for 72 hr	96-hr $LC_{50}$	"
Sheephead Minnow	Exposure to 46 vol % of same	96-hr $LC_{50}$	"
Channel Catfish	Exposure to 75 vol % of same	96-hr $LC_{50}$	"
Bluegill Sunfish	Exposure to 40 vol % of same	96-hr $LC_{50}$	"

SUMMARY OF TOXICITY OF FUEL OILS AND  
LUBRICATING OILS IN FISH (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Sheephead Minnow	Exposure to dispersion of 250 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	Anderson et al., 1974
"	Exposure to dispersion of 93 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
Silverside	Exposure to dispersion of 260 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to dispersion of 125 mg/l No. 2 fuel oil added to water	48-hr TL <sub>m</sub>	"
Sheephead Minnow	Exposure to >6.9 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
Sheephead Minnow	Exposure to 6.3 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	Anderson et al., 1974
Silverside	Exposure to 5.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 3.9 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"



# SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS IN WORMS

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Soil Nematodes	No. 2 fuel oil applied to 1.7 x 3.0 m plots of soil; application rate 2.5 kg/m <sup>2</sup>	Nemacidal after 6 and 12 months	Raymond et al., 1976
Marine annelids <i>Neanthes arena-</i> <i>ceodentata</i>	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	Rossi et al., 1976
"	Exposure to 3.2 mg/l No. 2 fuel oil dissolved in water	48-hr TL <sub>m</sub>	"
"	Exposure to 2.7 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
<i>Capitella</i> <i>capitata</i>	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 3.5 mg/l No. 2 fuel oil dissolved in water	48-hr TL <sub>m</sub>	"
"	Exposure to 2.3 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
<i>Neanthes arena-</i> <i>ceodentata</i> : 4-segment juveniles	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	Rossi and Anderson, 1976
"	Exposure to 8.4 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
18-segment juveniles	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 5.7 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
32-segment juveniles	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 5.4 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"

TL<sub>m</sub> - median tolerance limit

SUMMARY OF TOXICITY OF FUEL OILS AND  
LUBRICATING OILS IN WORMS (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
40-segment juveniles	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	Rossi and Anderson, 1976
"	Exposure to 2.7 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
48-segment immature addults	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 2.7 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
60-segment mature males	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 2.6 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
60-segment gravid females	Exposure to >8.7 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 4.2 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"

# SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS IN MOLLUSKS

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Scallops	Exposure to 12.5 mg/l No. 2 fuel oil in water	100% mortality in 24 hr	Tarzwel, 1971
Quahaug clam eggs 2nd-cleavage stage	Exposure to 0.43 mg/l No. 2 fuel oil dissolved in water	48-hr LC <sub>50</sub>	Byrne and Calder, 1977
2-Day old Quahaug larvae	Exposure to 1.3 mg/l No. 2 fuel oil dissolved in water	2-Day LC <sub>50</sub>	"
"	Exposure to 0.53 mg/l No. 2 fuel oil dissolved in water	10-Day LC <sub>50</sub>	"
Young adult soft shell clams	Exposure to 505 mg/l No. 2 fuel oil in water emulsion	96-hr LC <sub>50</sub> ; excessive mucus secretion; muscular narcotization	Stainken, 1976
"	Exposure to <100 mg/l No. 2 fuel oil in water emulsion	7-Day LC <sub>50</sub> ; excessive mucus secretion; muscular narcotization	"
Soft shell clams	5 months exposure to No. 2 fuel oil and jet fuel polluted waters	Male and female gonadal tissue invasive neoplasms possibly of germ cell origin; metastases to gills, genital and urinary pores, kidney, pericardium and red gland.	Barry and Yevich, 1975
Soft shell clams	Taken from oil-polluted waters	Gill and kidney hyperplasia	Stainken, 1976
7-hr old Larvae of Oysters and Mussels	Exposure to 10,000 mg/l No. 2 fuel oil in water dispersion	6-hr LC <sub>50</sub>	Renzoni, 1973
Oyster and Mussel eggs	Exposure to 1,000 mg/l No. 2 fuel oil in water dispersion	Reduced numbers of larvae developed	"

LC<sub>50</sub> - median lethal concentration

SUMMARY OF TOXICITY OF FUEL OILS AND  
LUBRICATING OILS IN MOLLUSKS (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Oysters	Exposure to dispersion of 0.1% or 10% No. 2 fuel oil added to water	50% mortality in 4 days	Anderson and Anderson, 1976
Oysters	Exposure to dispersion of 1% No. 2 fuel oil added to water	50% mortality in 8 days; 100% mortality in 14 days	Anderson and Anderson, 1976
Snails <i>Littorina</i> sp.	60 ml of kerosene poured over animals	Slight effect on crawling activity and attachment rates	Hadley, 1977
<i>Nassarius</i> <i>obsoletus</i>	Exposure to 1 to 4 $\mu$ g/l of kerosene dissolved in water	Interference with chemically-mediated food-finding behavior	Jacobsen and Boylan, 1973

# SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING OILS IN MARINE CRUSTACEANS

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Grass shrimp	Exposure to dispersion of 3.8 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	Anderson et al., 1974
"	Exposure to dispersion of 3.0 mg/l No. 2 fuel oil added to water	96-hr TL <sub>m</sub>	"
Mysid	Exposure to dispersion of 1.6 mg/l No. 2 fuel oil added to water	24-hr TL <sub>m</sub>	"
"	Exposure to dispersion of 1.3 mg/l No. 2 fuel oil added to water	48-hr TL <sub>m</sub>	"
Brown shrimp Postlarvae	Exposure to dispersion of 9.4 mg/l No. 2 fuel oil added to water	24-hr and 96-hr TL <sub>m</sub>	"
Grass shrimp	Exposure to 4.4 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 3.5 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
Mysid	Exposure to 2.6 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 0.9 mg/l No. 2 fuel oil dissolved in water	48-hr TL <sub>m</sub>	"
Brown shrimp postlarvae	Exposure to 5.0 mg/l No. 2 fuel oil dissolved in water	24-hr TL <sub>m</sub>	"
"	Exposure to 4.9 mg/l No. 2 fuel oil dissolved in water	96-hr TL <sub>m</sub>	"
Grass shrimp	Exposure to undiluted sol- uble fraction of 10% mixtures of No. 2 fuel oil in water	96-hr LC <sub>50</sub>	Scheier and Gominger, 1976
"	Exposure to 34.4 vol % di- lution of soluble fraction of 10% mixture of No. 2 fuel oil in water pre- viously UV irradiated for 72 hr.	96-hr LC <sub>50</sub>	"

LC<sub>50</sub> - median lethal concentration; TL<sub>m</sub> - median tolerance limit

SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING  
OILS IN MARINE CRUSTACEANS (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Grass shrimp	Exposure to water under 6-day-old No. 2 fuel oil slick prepared from 1 part oil and 360 parts water and UV irradiated for 6 days	50-min TL <sub>m</sub>	Scheier and Gominger, 1976
"	Exposure to same, but not irradiated during preparation	100% survival after 96 hr	"
Coon stripe shrimp	Exposure to 0.8 mg/l of No. 2 fuel oil dissolved in water	96-hr LC <sub>50</sub>	Vanderhorst et al., 1976
"	Exposure to 1.3 mg/l of No. 2 fuel oil dissolved in water	72-hr LC <sub>50</sub>	"
Amphipod Gammarus oceanicus Adults	Exposure to dispersion of 173 µl/l of No. 1 fuel oil in water	48-hr LC <sub>50</sub>	Linden, 1976
4-6 day old juveniles	Exposure to dispersion of 0.3 µl/l of No. 1 fuel oil in water	48-hr LC <sub>50</sub>	"
Adults	Exposure to solution of 5 µl/l of No. 1 fuel oil in water	100% mortality in 50 days; impaired swimming; loss of photophobia; reduced sexual activity; reduced numbers of offspring	"
Amphipod Boeckosimus affinis	Exposure to 1.0 ml/l of diesel fuel oil slick on water	24-hr LC <sub>50</sub>	Atlas, 1975
"	Exposure to 0.8 ml/l of paraffinic fuel oil slick on water	72-hr LC <sub>50</sub>	"
"	Exposure to 0.4 ml/l of aromatic fuel oil slick on water	16-day LC <sub>50</sub>	"

SUMMARY OF TOXICITY OF FUEL OILS AND LUBRICATING  
OILS IN MARINE CRUSTACEANS (CONT.)

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Copepod <i>Tigropus californicus</i>	Exposure to 1.0 ml/l of diesel fuel dispersed in water	100% mortality in 72 hr	Barnett and Kontogiannis, 1975
Copepod <i>Tigropus californicus</i>	Exposure to 0.50 ml/l of diesel fuel dispersed in water	100% mortality in 96 hr	Barnett and Kontogiannis, 1975
"	Exposure to <0.10 ml/l (87 mg/l) of diesel fuel in water	Reduced survival critical concentration	"
"	Exposure to 1.0 ml/l of kerosene mixed with water	85% mortality in 8 days	"
"	Exposure to <0.10 ml/l (83 mg/l) of kerosene in water	Reduced survival critical concentration	"
Cyclopoid Copepod Nauplii	Exposure to 50% dilution of soluble fraction of 10.1% mixture of No. 2 fuel oil in water	20% survival in 72 hr	Lee and Nichol, 1977
Calanoid Copepod Nauplii	Exposure to 50% dilution of soluble fraction of 10.1% mixture of No. 2 fuel oil in water	100% survival in 72 hr	"

# SUMMARY OF TOXICITY OF FUEL AND LUBRICATING OILS IN ECHINODERMS AND CORALS

SPECIES	EXPERIMENTAL PROTOCOL	RESULTS	REFERENCES*
Sand dollar eggs	Exposure to 20% dilution of soluble fraction of 10.1% mixture of No. 2 fuel oil in water	Abnormal fertilization, abnormal cleavage, reduced number of living larvae, deformed larvae.	Nicol et al., 1977
Sand dollar eggs and sperm	Exposure to 50% dilution of soluble fraction of 10.1% mixture of No. 2 fuel oil in water	No larvae developed from eggs; sperm 100% infertile after 30 min. exposure	Reimer, 1975
Coral Pocillopora sp.	Submerged for 1 minute in diesel fuel	Loss of almost all living tissue in 13 days	"
"	Diesel fuel poured over coral to cover for 30 min.	70% death of polyps in 17 days	"
Pocillopora, Pavona, Porites Psammocora	1-4 ml of diesel fuel added to water with organisms	Sustained mouth-opening response to food; no ingestion response in 50% of organisms; delayed feeding for 17 days after exposure	"



**APPENDIX I**  
**Isopleth Contours of the XM16**

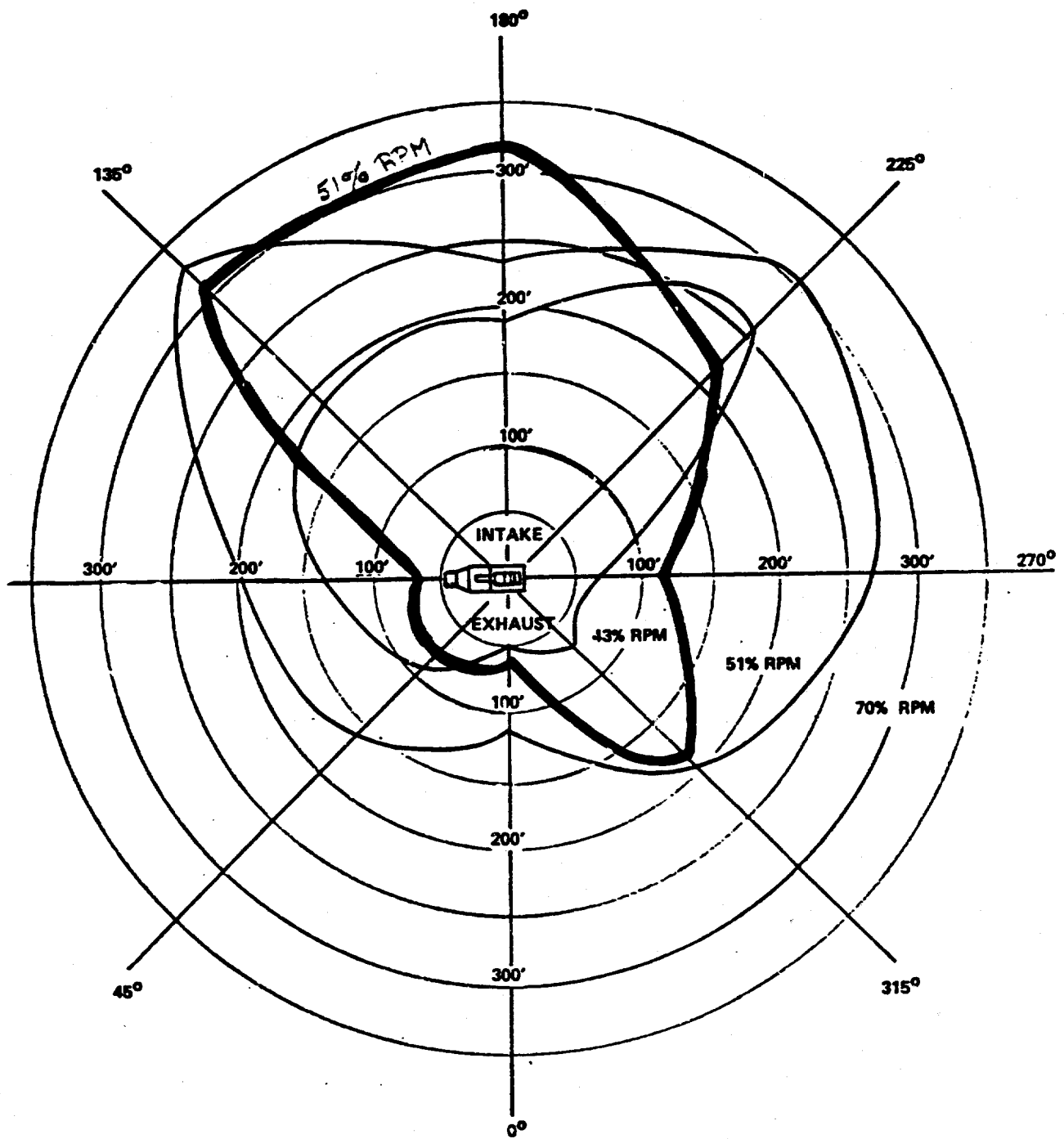


## APPENDIX I

### Isopleth Contours of the XM16

The following is the isopleth plot of 85dB-A contours for XM16 smoke generator. The maximum running speed of the J60-P-6 engine on the XM16 as stated by the Brunswick Corp. is 16,400 RPM. Three engine speeds are plotted, the usual running speed, 51% RPM, is outlined and labeled. The engine orientation may have been different for each engine speed. For the 51% contour the engine intake was toward 180° and exhaust end toward 0°. The truck driver cab always pointed toward 90°.





85dB-A Contours

Appendix I

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Officer-in-Charge Marine Corps Detachment Naval Explosive Ordnance Disposal Technology Center Indian Head, MD 20640	1	HQ AFSC/SDZ ATTN: CPT D. Riediger Andrews AFB, MD 20334	1
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Commanding Officer Naval Weapons Support Center Applied Sciences Department ATTN: Code 50C, Bldg 190 ATTN: Code 502 (Carl Lohkamp) ATTN: Code 5063 (R. Farren) Crane, IN 47522	1 1 1	USAF SC ATTN: AD/YQ (Dr. A. Vasiloff) ATTN: AD/YQO (MAJ Owens) Eglin AFB, FL 32542	1 1
US MARINE CORPS		AD/XRO Eglin AFB, FL 32542	1
Commanding General Marine Corps Development and Education Command ATTN: Fire Power Division, D091 Quantico, VA 22134	1	Commander Hanscom Air Force Base ATTN: AFGL/LYC (Dr. Barnes) ATTN: AFGL/POA (Dr. Frederick Volz) Bedford, MA 01731	1 1
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Department of the Air Force Headquarters Foreign Technology Division ATTN: TQIR Wright-Patterson AFB, OH 45433	1	APOSK/NE ATTN: MAJ H. Winsor Bolling AFB, DC 20332	1
		OUTSIDE AGENCIES	
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		Battelle, Columbus Laboratories ATTN: TACTEC 505 King Avenue Columbus, OH 43201	1

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#### ADDITIONAL ADDRESSEES

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USA Mobility Equipment Research and  
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Director  
US Night Vision and EO Laboratories  
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ATTN: DELNV-VI (Luanne Obert)  
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Science Applications Inc.  
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Creative Optics  
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Bedford, MA 01730

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McDonnell Douglas Astro Co  
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BMD Program Office  
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Dr. W. Michael Farmer, Assoc Prof, Physics  
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ARNG  
Operating Activity Center  
ATTN: NGB-ARI-E/Bldg E6810  
Aberdeen Proving Ground, MD 21010

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Commander  
USA Environmental Hygiene Agency  
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